(12)

RED ROCK DAM
DES MOINES RIVER, IOWA

REMEDIAL GROUTING
STAGE I

FOUNDATION REPORT

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MARCH 1993

US Army Corps
of Engineers
Rock Island District

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CENCR-ED-G 19 February 1993

MEMORANDUM FOR RECORD

SUBJECT: Distribution of Foundation Reports

1. Reference. ER-110-1-1811 Construction Foundation Reports, 15 December 1981.

2. In accordance with the above reference, copies of the Red Rock Dam Remedial Grouting - Foundation Report Stage I will be distributed accordingly.

a. CENCD-PE-ED-TG - 2 copies with one forwarded to HQUSACE (DAEN-CECW-ED) for Review and Approval. Upon approval:

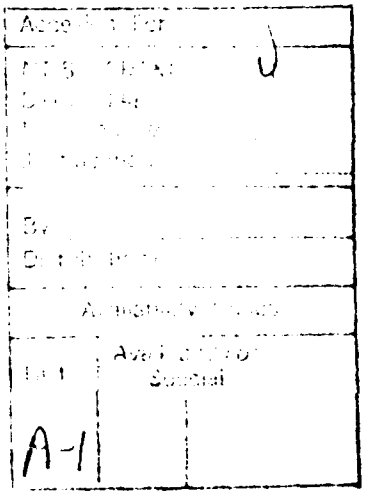
b. CENCR-CD-J - 2 copies
CENCR-OD-RR - 1 copy
CENCR-ED-D - 1 copy
CENCR-ED-G - 4 copies
CENCR-IM-CL - 1 copy (library)

c. Defense Technical Information Center (DTIC), DTIC/DA-2 Cameron Station, Alexandria, VA 22314 - 12 copies

d. U.S. Army Waterways Experiment Station Technical Library, P.O. Box 631, Vicksburg, MS 39180 - 1 copy

e. Library, HQUSACE (DAEN- ASI), Washington D.C. 20314 - 2 copies

VERNON H. GREENWOOD, P.G.
District Geologist



CENCD-PE-ED-T (CENCR-ED/16 Mar 93) (1110) 1st End
Mr. Westall/(312) 353-5734 23 SEP 1993
SUBJECT: Red Rock Dam, Des Moines River, Iowa, Remedial Grouting Stage 1, Foundation Report, March 1993

Cdr, North Central Division, U.S. Army Corps of Engineers,
111 N. Canal St., Chicago, IL 60606-7205

FOR Cdr, Rock Island District, ATTN: CENCR-ED SEP 24 1993

1. The Foundation Report is approved subject to the comments below:

a. Page 16, paragraph 6. CENCR-G should prepare a supplementary geotechnical report that evaluates dam stability and uplift in the downstream toe area. In this analysis, both the old and new observation well data should be used to ascertain improvements to dam stability and the need for future work. (The uplift analysis of Orwell Dam is provided at enclosure 2 for guidance in performing the stability analysis.)

b. Grouting. When grout takes are large and no pressure build-up is observed, rely on thickened grouts and pumping rate control, in-lieu of delays; eventually pressures will build up. Also, overruns on grout quantities should not be a controlling factor in your efforts to effectively grout.

2. The HQ, NCD, POC is Mr. Grant Westall, CENCD-PE-ED-T, (312) 353-5734.

FOR THE COMMANDER:

for Donald J. Leonard

JOHN P. D'ANIELLO, P.E.
Director, Engineering and
Planning Directorate

2 Encls
wd encls 1
added encl 2
2. Orwell Dam Uplift Analysis

DEPARTMENT OF THE ARMY
ROCK ISLAND DISTRICT, CORPS OF ENGINEERS
CLOCK TOWER BUILDING—P.O. BOX 2004
ROCK ISLAND, ILLINOIS 61204-2004

ED-T

REPLY TO ATTENTION OF

CENCR-ED

16 March 1993

MEMORANDUM FOR Commander, U.S. Army Engineer Division, North Central, 111 N. Canal Street, 12th Floor, Chicago, IL 60606

SUBJECT: Red Rock Dam, Des Moines River, Iowa, Remedial Grouting Stage I, Foundation Report, March 1993

1. Reference ER1110-1-1801, 15 Dec 81, subject: Construction Foundation Reports.

2. Subject report is forwarded for your review. The report has been prepared in accordance with the above reference.

FOR THE COMMANDER:

Robert W. Kelley

ROBERT W. KELLEY, P.E.
Chief, Engineering Division

Encl (trip)

RED ROCK DAM
DES MOINES RIVER, IOWA

REMEDIAL GROUTING
STAGE I

FOUNDATION REPORT

MARCH 1993

US Army Corps
of Engineers
Rock Island District

RED ROCK DAM - LAKE RED ROCK
DES MOINES RIVER, IOWA
REMEDIAL GROUTING PROJECT

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REMEDIAL GROUTING PROJECT

1. INTRODUCTION

a. Location. Red Rock Dam is located in Marion County, Iowa on the Des Moines River about 142 miles upstream from point of discharge into the Mississippi River. The nearest cities are Pella and Knoxville, which are located about 4 and 6 miles northeast and southwest, respectively. A general location map is shown on plate 1.

b. Description.

The dam consists of a rolled earthfill embankment and a gravity concrete control section. The dam, at crest elevation of 797 feet above mean sea level, is about 5,200 feet long and 95 feet high above the flood plain. A compacted impervious cutoff trench to bedrock and a grout curtain in the rock are provided for underseepage control. A horizontal and inclined sand drain controls any through seepage. The upstream slope is riprap, and the downstream slope is grass. A county road of Portland Cement concrete crosses the top of the dam. The gated concrete spillway is an ogee section founded on bedrock with a crest at elevation 736. The spillway's five crest gates are 45 feet high and 41 feet wide, separated by 9-foot wide piers. The outlet works consist of fourteen 5-foot by 9-foot gated conduits that extend through the spillway section and discharge into the stilling basin. The non-overflow concrete sections of the dam at each end of the spillway are of the gravity type and are keyed into the foundation rock. A general plan of the dam is shown on plate 1. Typical sections of the dam are shown on plate 2.

The full flood control level is elevation 780. The conservation pool level has been raised from an originally planned elevation of 720 to elevation 728, 734, and 742 (Spring 1992). At full flood control elevation, the pool covers 65,400 acres. At elevation 742, the reservoir contains approximately 1,750,400 acre-feet of water, of which 1,494,900 is allotted to flood control and 255,500 forms a permanent pool.

c. Purpose of the Report. The purpose of this report is to describe the program of remedial grouting in the left abutment and rock underlying the earthen dam from Station 25+00 to 36+00 and to insure a permanent record of the foundation conditions encountered and methods employed to treat those conditions.

d. Authority for the Report. Authority for this report is by the Department of the Army, U.S. Corps of Engineers regulation ER-1110-1-1801, Construction Foundation Reports dated 30 June 1982. This regulation states that it is a requirement to prepare as-built foundation reports for major or unique projects.

e. Project History.

The Red Rock Reservoir and appurtenant works on the Des Moines River were approved for construction under authority of the Flood Control Act, approved 28 June 1938. Authorization was for flood control and low flow augmentation. Initial planning funds were made available in 1947 and again in 1957 after a delay caused by the Korean War, with construction funds becoming available in 1960. Construction began in May 1960. The dam was constructed in three stages and was completed in May 1969.

During the first year of operation, seepage was noted along the left downstream toe and in the field just downstream of the dam during high pools. This problem has been recurrent with high pools and has been closely monitored. Additional observation wells and piezometers have been installed in the embankment, left abutment, foundation rock, and downstream areas (see paragraph 5). A number of comprehensive studies and reports documenting this seepage phenomena and related groundwater geochemistry have been completed over the years and are referenced herein as References a, c-g, j, p, and q.

f. Purpose of Construction. The purpose of the construction was to attempt to reduce geohydrologic deficiencies as described in References a through g and p. This was done to insure compliance with Corps of Engineer Safety Assurances and Operational Standards as described in Reference f. The construction project consisted of the following primary activities:

(1) Drilling through the overburden and/or embankment to rock surface.

(2) Setting casings 3 feet into the rock surface and sealing.

(3) Drilling into the rock by downstage techniques.

(4) Washing and pressure testing zones and stages of the rock.

(5) Gravity and pressure grouting of the rock to acceptable pressure refusals.

g. Contractors, Supervision, and Quality Control. A contract (DACW25-91-C-0050) for Stage I of this work (Station 25+00 to 3[illegible]00) was awarded to the prime contractor, the Judy Company of Kansas City, Kansas on 18 July 1992. The Douglas Drilling Company of Douglas, Wyoming acted as a subcontractor during the drilling and installation of casings through overburden and embankment. Contract supervision and quality control were administered by the vice president of the Judy Company and his senior supervisory staff. Normally there were two of these people on the job consistently. Work on this project began on 4 September 1991 and was shut down for the winter on 26 November 1991. Work was resumed on 31 March 1992 and completed on 14 October 1992.

h. Key Resident and Design Staff. The Area Engineer and COR for this project was Mr. LeRoy Corey, CD. Mr. Tom Barickman, CD, and Mr. Richard Bauer, TDY from the Detroit District, served as inspectors. Mr. Patrick Jordan, a geologist from the Little Rock District also acted as grouting inspector during a portion of the 1992 work. Mr. Vern Greenwood, District Geologist, oversaw the entire project and was initially assisted by Mr. Joseph Waring, ED-D. The design staff consisted of Project Engineer Mr. Dave Wehrley, ED-DM, and Mr. Vern Greenwood, ED-G; they were supervised by Mr. George Mech, Chief of ED-G, Mr. Donald Logsdon, Acting Chief of ED-D, and Mr. Dale Rossmiller, Chief, ED-D.

2. FOUNDATION EXPLORATIONS

a. Investigation Prior to Construction (Main Dam). Scores of borings and field inspections were made prior to construction of the main dam. Logs of these are shown and described in the Design Memorandums (Ref. h). Many other investigations into the character of the foundation were conducted prior to and during construction. These are documented in the foundation reports (Refs. n and o).

b. Investigations During Construction (Main Dam). During the latter phases of Stage III construction, a number of exploratory borings and observation wells were completed. Data from this work is shown on the plan and section on plate 3. During 1987 and 1988, new observation wells were installed. This work was done by contract with the Terracon Company. Detailed logs of these borings and instrumentation are shown in Reference i and are shown in plan and section on plate 3.

c. Investigations During this Contract (Remedial Grouting). Specifications for this contract called for drilling 1,000 feet of exploratory holes. During the initial construction (September - November 1991), five NQ

wireline exploratory holes were taken. In the 1992 work, an additional eleven exploratory borings were taken. The two purposes of these exploratory holes were to better define the thickness of the overburden/embankment and to clarify the elevation and character of the rock surface. Additionally, these exploratory holes gave a better picture of the rock for the purposes of zoning and staging. Water pressure tests in the exploratory holes were also of value in the determination of the grouting program within certain sections of the curtain. Exploratory holes were completed by the prime contractor between Stations 25+00 and 36+05 and are designated accordingly:

Exploratory Hole No.	Station	Offset	Depth Drilled into Rock ft.	Total Depth
P-1X	25+00	15'US	13/22.5*	111
S-3X	25+50	15'US	52	178
P-17X	28+20	15'US	49	178
S-22X	29+30	15'US	66	178
QS-23AX	29+52.5	15'US	70	178
TP-25X	29+85	15'US	75.4	178.9
P-27X	30+20	15'US	76.5	178
QP-28BX	30+47.5	15'US	81.2	174.2
P-32X	31+20	15'US	85	178
TS-36X	32+15	15'US	79.5	180.5
P-37X	32+20	15'US	68	178
P-42X	33+20	15'US	69	178
P-43X	33+40	15'US	71	178
P-47X	34+20	15'US	77	178
S-53X	35+50	15'US	83	178
TP-56X	36+05	15'US	77.3	178.9

* Note: Refer to paragraph 4f

The location, boring logs, and geologic profiles generated from these exploratory holes are shown on plates 4a thru 4d. Pressure tests and grouting records are included in Appendixes A-1 and A-2 and are shown on plate 6 (a-e). Photographs of these cores are on file in CENCR-ED-G.

3. GEOLOGY

a. Regional Geology. Red Rock Dam lies within the dissected Till Plains Section, Central lowlands Province of the Interior Plains. The region is typified by submaturely to maturely dissected till plains commonly found throughout this midwestern area. The region is drained by the Des Moines River, a major tributary to the Mississippi River.

b. Site Geology

(1) Physiography. The Des Moines River in the reach of the reservoir meanders through a flood plain 1 to 2 miles in width. In preglacial or interglacial time, the valley was some 30 to 40 feet deeper than at present; it filled to its present level with glacial outwash and alluvium. Bedrock in the valley walls and in the floor beneath the outwash through most of the reservoir is of the Des Moines series of the Pennsylvanian system. The bluffs are a maximum of about 150 feet above the flood plain. At and adjacent to the dam, the bedrock beneath the approximate elevation of the flood plain is of the St. Louis formation, Mississippian system. The valley sides are steep to gentle through the reservoir. At the dam, the right slope is about 1 on 7, and the left averages about 1 on 9. A geologic section is shown on plate 3 and 5.

(2) Description of Overburden. Bluffs and valley sides at the dam are covered with variable thicknesses of glacial materials which in general are thinly covered with loess. High in the right bluff, particularly in the area of the field office and radio tower, a formation exists that might be considered overburden, but which is more properly a member of the Pennsylvanian system. This formation is a thinly laminated weathered siltstone that contains random masses of unweathered sandy limestone up to several cubic yards in size. The flood plain is made up of alluvial silts and clays up to a maximum of 14 feet thick, underlain by sands and gravels.

(3) Bedrock Stratigraphy. The division between Pennsylvanian and Mississippian rocks at the dam is, on the average, at about the elevation of the flood plain. Within a half mile, however, Mississippian rock may be found 40 feet higher and Pennsylvanian rock 30 feet lower. The rocks are chiefly shales of the compaction type with younger Pennsylvanian interbedded (usually not persistent) and strata of sandstone, siltstone, limestone, and coal. Some limestones are persistent over considerable areas. The Mississippian rocks to a depth of about 70 feet below the flood plain are alternately limestones and sandstones. They form distinct units that persist throughout the site. In some areas at the base of these rocks, domes of gypsum with thicknesses of up to 17 feet have been found. Recent partial removal of gypsum by solution has resulted in a horizon of unconsolidated or poorly consolidated detrital material. Beneath the gypsiferous horizon to an additional depth of at least 70 feet are massive dolomitic hard shales interbedded with thin strata of softer black shales, some of which are persistent.

(4) Bedrock Structure and Weathering. The regional dip over a wide area about the reservoir is about

10 feet to the mile south-southwesterly. With minor local variations, this trend holds across the damsite. The formation of the gypsum domes resulted in intense fracturing of the overlying limestone and sandstones. After cutting the Des Moines Valley, groundwater had free access through the fractured rocks to the gypsum, resulting in removal of some of the gypsum. Such removal has resulted in subsidence and further fracturing of the overlying rocks. The space formerly occupied by gypsum has been partially filled with detrital material, silts, clays, sands, and fragments of rock, from the overlying rocks. The ready access of groundwater to the fractured formation has resulted in some weathering along the joints and seams, a solution of limestone with clay filling of the cavities, and leaching of sandstone. The cementing material in the latter is calcium carbonate. Uncemented phases of the sandstone (product of leaching) are generally less prevalent with depth.

(5) Groundwater Leaching and Solution Activity

Because there has always been a concern for safety ever since the dam was built, the groundwater regime at Red Rock Dam has been extensively studied by geologists and engineers. These studies and reports are given in Appendix C as References a-e, j, p, and q. Reference g is cited specifically since it is the most recent and comprehensive. This study by the United States Geological Survey concludes much of the previous work and additionally covers recent findings of a geohydrological and geochemical nature and evidence of underseepage. For those most interested in a comprehensive investigation, this reference is a reading must. Reference j is a synopsis of the history of investigations, and Reference p is the basis for the justification of the remedial grouting contract.

The current status of the groundwater and underseepage conditions are best characterized by excerpts from Reference g and are given herein by permission of the author:

"The St. Louis Limestone, which consists of interbedded sandstones and carbonates with solution collapse features resulting from partial removal of a basal evaporite zone, forms the bedrock foundation of the dam in the river valley. The soluble gypsum and anhydrite in the evaporite zone have the potential to be removed in greater quantity with increasing seepage velocities and volumes. Solution channels may develop as material is removed from the bedrock foundation, which could result in the collapse of overlying strata, thereby threatening the integrity of the earthen dam.

The potentiometric surface in the overburden on the southwest side of the dam has an extremely steep

hydraulic gradient from the reservoir through the dam to the downstream observation wells, which implies expected small permeability and minimal seepage through the dam and embankment materials. A lesser hydraulic gradient exists on the northeast side of the dam, which could indicate excessive seepage through embankment material from larger than expected hydraulic conductivity or underseepage through bedrock. Statistical analysis of water-level changes in the reservoir and in observation wells completed in the evaporite stratigraphic horizon on the northeast side of the dam indicates a hydraulic connection between the reservoir and wells.

Direct evidence of the existence of a connection between the reservoir and the groundwater system is provided by chloride concentration data. Maximum chloride concentrations occurred in the reservoir water in the early spring of 1989. Chloride concentrations reached a maximum in groundwater from bedrock and overburden observation wells on the northeast side of the dam 1 to 4 months after their maximum in the reservoir. Underseepage of reservoir water occurs through the basal evaporite zone of the St. Louis Limestone and through the glacial sands in the northeast bluff between the bedrock surface and the base of the dam fill.

The increased hydraulic head imposed on the system by the impounded waters of Lake Red Rock causes recharge and flow to the deeper bedrock aquifers in the immediate vicinity of the dam. This effect is manifested in the observation wells along and downstream from the dam axis, implying flow through the grout curtain in the bedrock foundation of the dam. There is potential for dissolution of the gypsum and anhydrite in the bedrock foundation, because reservoir water and shallow groundwater in the vicinity of the dam are undersaturated with respect to these evaporite minerals."

(6) Earthquakes. Red Rock Dam is located in seismic zone 1, and capable faults or recent earthquake epicenters are absent in the region.

4. FOUNDATION TREATMENT

a. General

Plans and specifications for the contract drilling and grouting were designed by the Rock Island District Geotechnical and Design Branches. The work for stage one (Sta. 25+00 to 36+00) consisted of constructing a single-line vertical grout curtain.

The contract called for installation of steel-cased holes through the overburden or embankment with a positive seal into the founding rock. This was amended to allow 3-inch PVC casings instead, since they were less expensive and could be grouted in place rather than removed. The subcontractor used conventional rotary water drilling for these installations, and the holes were predrilled through the embankment/overburden ±3 feet into rock. The schedule 40 PVC casings were set into rock and grouted therein by pumping 3:1 neat cement grout through the PVC into the rock and until the grout resurfaced at the header around the annular space.

b. Significant Dates

(1) Initial mobilization and setup began on 4 September 1991. Actual drilling and grouting was started on 19 September 1991. Progress was very slow initially since the drill rig was in need of repair.

(2) Drilling and grouting was terminated on 26 November 1991 for winter shutdown.

(3) The 1992 construction was resumed on 31 March 1992 and was completed on 14 October 1992.

c. Drilling and Grouting Equipment. Equipment utilized for drilling and installation of the grout curtain is shown below:

Quantity	Item
1	GEOREX T500 S/S Auger Drill
1	Chicago Pneumatic CP350 Rotary Drill
2	Air driven 3-inch submersible water pumps
1	Skid steer end loader - Case 1840
1	Flat bed truck - F700
1	Mechanics truck - 1 ton
1	500-gallon fuel tank
1	Office trailer for contractor
1	Office trailer provided by contractor for COE
1	Multiquip 185 CFM air compressor
2	Pickup trucks
1	24 cubic foot grout plant (portable)
1	3/4-ton Dodge pickup truck
1	Cement Tech trailer mounted automated grout plant, unit 313, 36 cubic foot capacity
-	Grout headers, pressure gages, and packers
-	3-inch schedule 40 PVC, bell joint casing - 20-foot lengths

d. Location of Grout Curtain. The grout curtain begins in the left abutment of the dam and is set parallel to the centerline of the cut-off trench, 15 feet upstream.

Stage I construction runs from Station 25+00 to 36+00. Stage II construction will run from Station 36+00 to 55+00.

e. Design of Grout Curtain. The grout curtain was designed by the Rock Island District Geotechnical and Design Branches. The list of references contains several reports depicting the foundation and geohydrologic conditions that were the logic for proposing a remedial grouting program. Reference f, "The Reconnaissance Report for Dam Safety Assurance" with three endorsements, and Reference p, "Seepage Study and Design Analysis Report", are the basis for the authorization of the remedial grouting program. The basic design was intended to be completed with primary holes "p" set on 20-foot centers and secondary holes "s", or split-spaced holes, set on 10-foot centers between the primaries. Tertiary and Quaternary holes were also installed at 5- and 2-1/2-foot spacing, respectively, in some reaches and are shown accordingly on grouting profile plates 6a through 6e. The curtain is from the top of rock down to elevation 620 and was grouted by the zone and down-stage method.

f. Drilling Difficulties

(1) Overburden and Embankment. The general sequence utilized for installation of the casing (3-inch schedule PVC pipe) was completed by the subcontractor, Douglas Drilling Company, and consisted of rotary drilling with water through the overburden or embankment into the rock surface. Techniques involved the use of 4 3/4-inch tricone rotary and fishtail bits. In several cases at the beginning, numerous retries had to be negotiated since cobbles, broken stone, and gravel were encountered within the material. Once rock was reached, it was penetrated approximately 3 feet and the casing was grouted therein. In some cases, drilling water was restricted when wind blew debris into the sump area on the lake. Eventually, a water supply line was installed that led from the permanent waterline at the campground entrance near Station 27+00. Since drilling through the overburden encountered cobbles, sand and gravel, as well as broken rock, and caused many problems for the drill crew, it was difficult at first for the contractor to determine the top of competent rock (see also paragraph 4f(2)). It was determined that primary hole casings in holes P-1 through P-10 and P-12 through P-14 were set in sand and not rock. These holes were backfilled with grout and abandoned, and only the secondary holes S-1 through S-10 and beyond were used for grouting. The grout takes were negligible (see paragraph 4h). Drilling of the embankment beyond station ±30+00 was pretty much routine and was done by both the prime contractor and subcontractor.

(2) Rock Drilling and Coring.

Drilling in rock was accomplished using 2-7/8-inch rotary rock bits, and rock coring was performed with NQ wireline equipment. Difficulties were encountered with both rock drilling and coring at first. Different techniques were attempted by the drillers until a best method was found. Various drilling rates, pressures, and bit types were employed, and a more experienced driller was brought on site.

Core drilling in the first exploratory hole (P-1X) was only partially successful. About 14 feet of rock was cored with very poor recovery except for about a 2-foot zone of hard rock, which was recovered and believed to be the rock surface. This zone was initially used as a basis for setting the original casing in holes P-1 through P-10. After the hole was grouted, subsequent coring proved rock to be at lower elevations, and casings for all subsequent holes were set accordingly. It was also determined that the coring bit was defective and was replaced, which resulted in faster drilling and better core recovery.

Some rock drilling in the lower more competent rock was completed using a 3-inch diameter Bullrock Downhole Air Hammer. Use of this equipment was approved by NCD as well as OCE. The work was performed without incident and went much faster than conventional drilling methods.

g. Grouting Methods and Techniques.

In general, the following procedures were employed for drilling, pressure testing, and grouting: (1) drill through any grout in the surface/embankment casing including the grout plug used to seal the casing into rock; (2) wash out hole and check for leakage in the casing and embankment/overburden rock contact zone; (3) drill, wash, pressure test, and grout the primary holes in the first zone (these were secondary holes between Stations 25+00 and 26+70 as described above); and (4) repeat preceding steps for underlying zones as shown on Plate 6a through 6e.

The single-line drilling and grouting operation was accomplished using the zone, split spacing, and stage grouting methods. Between Stations 25+00 and 27+00, two zones were required for primary holes; these were secondary holes S-1 through S-10. From Station 27+00 to 28+70, both primary and secondary holes were grouted in two zones. Beyond Station 28+70 to the end of Stage I (36+00) primary through quaternary holes were grouted in three zones.

All holes were washed prior to water pressure tests and sealed at the surface with a packer sponge prior

to testing/grouting. A water manifold with a pressure gage and adjusting valves was set on the header casing for pressure tests. The pressure guidelines were established in the field and, unless otherwise directed, were as shown below.

Water Pressure Test Pressures (PSI)	
Location	Pressures
Zone 1(Top of rock to El. 670)	10-20-10 (5 min @ ea press)
Zone 2(Elev. 670 to 640)	20-40-20 (5 min @ ea press)
Zone 3(Elev. 640 to 620)	30-60-30 (5 min @ ea press)

The grout was mixed at the automated batch plant in a 36 cubic foot capacity mixer and pumped to a 24 cubic foot holding mixer. The grout was then pumped from the holding mixer to the manifold header at the top of the grout hole. Batch quantities were carefully monitored during mixing and were confirmed at the end of each grouting operation.

Grouting on a hole was usually started at either a 4:1 or 3:1 water cement ratio. The majority of grout was pumped at the 3:1 mix. In zones having excessive grout takes, the mix ratio was reduced accordingly and as directed to as low as 0.6:1 ratio. Holes that had extreme grout takes were grouted with a sanded mix. These holes included P-25, P-37X, and P-56. Grout pressure guidelines were established prior to the contract award and were adjusted in accordance with field standards as applied to the geology and in conjunction with results of water pressure tests. Unless otherwise directed, grouting pressures were as shown below:

Grouting Pressures (PSI)				
	Mix Design			
Location	4:1,3:1	2:1	1:1	<1:1
Zone 1	5	Gravity	Gravity	Gravity
Zone 2	30	25	10	Gravity
Zone 3	60	45	30	Gravity

The use of Microfine cement was employed in reaches where we thought we could penetrate more effectively into the bedrock fractures than the contractor had with the conventional grout. Attempts were made at the following hole locations: TS-22, TP-23, TS-23, TP-28, TS-28, TP-31, TS-31, TP-32, TS-32, TP-33, TS-39, TP-40, TS-40, TS-41, TP-

42, TS-48, TP-49, TS-49, TS-50, TP-51. Details of grouting are shown in the Grouting Compendium Tables (Appendix A-1).

In looking at exploratory cores taken adjacent to the Microfine grout hole, it was noted that there was little difference in the penetration characteristics between the Type II Cement and the Microfine product.

Upon completion of grouting within a zone and when the grout had set sufficiently, the hole was washed out and the underlying zone was prepared for drilling. This method was repeated for adjacent holes within a section and for each successive zone until complete. Table A-1 is a complete grouting compendium, and table A-2 illustrates the effectiveness of progressive grouting in high take areas. A profile of the completed grout curtain, with all related significant data, is presented on Plates 6a thru 6e. From the contractor's past experiences, pulling casings after grouting was completed was not successful; therefore, the PVC casings were left in place and backfilled with 1:1 grout and were cut off at the surface.

h. Quantities and Costs

Item	Description	Quantity	Unit	Unit Price	Cost
0001A	Mobilization and demobilization	1	LS	60,000	60,000
0001B	Drilling in dam embankment, incl. casing and backfilling	22,225	LF	10	222,250
0001C	Drilling grout holes	12,102	LF	12	145,224
0001D	Drilling exploratory holes	1,029	LF	25	25,725
0001E	Portland Cement in grout	15,133	CF	4.4	66,585.2
0001F	Mineral filler in grout	230	CF	4	920
0001G	Sand in grout	458	CF	1	458
0001H	Placing grout	15,182	CF	3.5	53,137
0001I	Connections to grout holes	464	EA	25	11,600
0001J	Washing and pressure testing	174.75	HR	40	6,900

Item	Description	Quantity	Unit	Unit Price	Cost
0001K	Microfine cement in grout	35,420	LB	.70	24,794
0001L	Post grouting pressure testing	2	HR	40	80
0002A	Construct Observation Wells				
0002A1	R-91-1	1	LS	6,065	6,065
0002A2	R-91-2	1	LS	6,585	6,585
0002A3	R-91-3	1	LS	2,935	2,935
0002A4	R-91-4	1	LS	2,935	2,935
0002A5	R-91-2A	1	LS	7,945	7,945
0002B	Furnish and Install Piezometers				
0002B1	R-91-1	1	LS	2,560	2,560
0002B2	R-91-2	1	LS	3,000	3,000
0002B3	R-91-3	1	LS	1,335	1,335
0002B4	R-91-4	1	LS	1,335	1,335
0002B5	R-91-2A	1	LS	2,890	2,890
0003	Traffic control	1	LS	41,700	41,700
0004	Office trailer mobilization	1	LS	1,936	1,936
0005	Office trailer monthly rent	12	MO	601	7,212
			Subtotal		$706,106.20
0006	VECP-Piezometer installation changes	1	LS	(3690)	(3690)
			Approximate Total Cost		$702,416.20

i. Results and Conclusions

The total amount of 35,356 lineal feet for drilling grout holes includes 22,225 lineal feet of drilling through overburden, 12,102 lineal feet of drilling grout holes, and 1,029 lineal feet of drilling exploratory holes. The total amount of grout placed (solids) was 15,182 cubic feet. Therefore, it is calculated that with 13,131 lineal feet of grout and exploration holes being grouted that 1.15 cubic feet of grout was placed per lineal foot in the grouting zones.

Further examination of Table A-2 shows a repeated pattern of larger takes in the primary and some secondary holes with dramatic decreases in the adjacent tertiary and quaternary holes. Thus indicating that the grout curtain in the areas of original high takes have been grouted to within acceptable limits. Higher take zones such as those in holes in the vicinity of stations 29+80, 32+20, and 36+00 (holes

P-25, P-37X, and P-56, respectively) were initially grouted with a 3:1 mix and progressively thickened to refusal using sanded mixes (see Table A-1). During the original grouting (years 1966-67) along these same reaches (Stations 29+00 to 36+00), the average grout take per lineal foot was ±4.05 cubic feet to obtain refusal. The new grouting average of 1.15 take per lineal feet is due to deterioration of the original grout curtain.

A number of high take zones (possibly cavities) were encountered during both drilling and grouting of the initial treatment (1966-67), and since various amounts of seepage through the system have been defined since 1969, it was the intent of the remedial grouting to reduce seepage and preserve the foundation by this second contract. Since the new contract drilling and exploratory holes revealed additional, remaining, or newly formed seepage passages, broken zones, and some cavities, it can be concluded that (1) the original contract grouting was only partially successful or (2) it has deteriorated to some degree. In either case, judging from the grout takes, pressures, and final refusals that the remedial grouting for Stage I showed, it should have a positive effect in the reduction of seepage.

Since grout curtains are seldom 100% effective, one should not expect to see complete and total changes nor will any changes be immediately obvious. Recommendations are discussed in paragraph 6b.

5. FOUNDATION INSTRUMENTATION

a. Types and Purpose. In general, there are four types of foundation instrumentation at Red Rock Dam. They are as follows: (1) survey points, which include surface reference points that are used to measure vertical and lateral movements, (2) monolith reference monuments and displacement Indicators (in the concrete structure), (3) a slope indicator in the right abutment used to monitor slope movement below the administration building, and (4) observation wells and piezometers. Types 1 through 4 have been monitored regularly, and readings and summaries were included in the periodic inspections and most recently in Reference r. The most important instrumentation associated with grouting is, of course, the installation of observation wells and piezometers that measure pore water pressure both in the embankment and founding rock as well as in the unconsolidated till and bedrock in the left abutment, alluvial, and glaciofluvial materials and bedrock just downstream from the dam.

b. Prior to Construction. Prior to original construction, only a few of these installations were made.

Since the embankment completion, large numbers of piezometers have been installed over the years at numerous locations throughout the structure, in the abutments, and some upstream and several downstream installations. Many of these were installed during and after construction and have been continuously monitored over the years. Reports cited in the references deal with this information. The most recent installations are illustrated and discussed in References i and s.

c. During Construction. During construction of Stage I grouting (1992), one piezometer was installed just upstream of the dam. It is well no. R-92-1 in the camping area.

d. After Construction. After the construction of the Stage I curtain, four additional piezometers were installed, two along the top of the dam (R-92A and R-92-2) and two on the downstream berm (R-92-3 and R-92-4). These new wells were installed to better define the effectiveness of the remedial grout curtain and will be used in the programmed United States Geological Survey follow-up study. Details of these installations are shown in Reference s of this report as well as on Plate D-3.

6. POSSIBLE FUTURE PROBLEMS

a. Conditions That Could Produce Problems. With the construction of any large water retaining structure, whether it be concrete earth/rock fill or a combination, comes the concern for possible future problems. The range of problems at Red Rock should become of less significance now that a comprehensive remedial grouting program has been established. To date, the dam has performed as it was designed to. With the near future completion of foundation treatment, it is believed that concerns for greater seepage will be reduced.

b. Recommended Observations/Studies

There is an on-going study and analysis of data collected from observation wells, grout gallery flow, seepage points, and weir readings and of the general overall condition of the entire structure. These observations are performed routinely and as frequently as daily during high head conditions. They have most recently been reported in References g and r.

Geochemical analysis is made from observation well samples in wells 5RA, 5RB, 23-R, 29-0, 30-0, and R-87-4 by contract with Iowa State University. Previous information from this source has been used by the United States Geological Survey in the completion of Reference g.

Further analysis by CENCR-ED-G is planned using the Iowa State Data, and the United States Geological Survey has a proposal to NCR for a geohydrologic study to evaluate the effectiveness of the remedial grouting. The proposal is for an Evaluation of Underseepage using stable isotopes, which is proposed to supplement and corroborate chloride tracer data used as evidence of the underseepage study (Ref. g).

Special attention will be in order when monitoring the new observation wells upstream of the remedial grout curtain, i.e. R-92-1, R-92-2A, and those downstream (R-92-2, -3, and -4).

Additional remedial grouting from Station 36+00 through 55+00 has been authorized and will be completed during FY 93 and 94.

Appendix A

Tables

Table A-1

Grouting Compendium

RED ROCK DAM
PRIMARY AND SECONDARY COMPENDIUM

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
P-1	25+00	75	723	723	687	36	1	4:1	5.1			10	4.0	20	5.1	ABANDON
S-1	25+10	145	653	653 640	640 620	13 20	2 3						.04 0	40 60	TIGHT	
P-2	25+20	75	723	723	683	40	1,2	4:1	9.6			30	3.7		9.6	ABANDON
S-2	25+30	138	660	660 640	640 620	20 20	2 3						.04 0	40 60	TIGHT	
P-3	25+40	72	726	726	680	46	1,2	4:1	5.5			20	4.0	0	5.5	ABANDON
S-3X	25+50	126	672	672 637	637 620	35 17	2 3	4:1	11.8			30	3.0 4.2	40 30	11.8	
P-4	25+60	81	717	717	680	37	1,2	4:1	9.1			30	6.8	0		ABANDON
S-4	25+70	141	657	657 640	640 620	17 20	2 3	1:1	8.7			10	.02	30	8.7	
P-5	25+80	81	717	717	680	37	1,2									ABANDON
S-5	25+90	141	657	657 640	640 620	17 20	2 3	3:1	3.4			30	.42 0	40 60	3.4	
P-6	26+00	81	717	717	680	37	1,2						6.9			ABANDON
S-6	26+10	128	670	670 640	640 620	30 20	2 3	3:1	3.7			60	.12 .72	40 60	3.7	
P-7	26+20	86	712													ABANDON
S-7	26+30	132	666	666 640	640 625	26 15	2 3	3:1	0.9			30	.14 .03	40 60	0.9	
P-8	26+40	88	710													ABANDON

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
S-8	26+50	126	672	672 640	640 620	32 20	2 3	3:1	1.4			30	.2 .03	40 60	1.4	
P-9	26+60	90	708	708	683	25	1,2						6.5			ABANDON
S-9	26+70	126	672	672 640	640 620	32 20	1,2 3						.04 .02	40 60		
P-10	26+80	88	710	710	680	30	1,2						6.5	0		ABANDON
S-10	26+90	122	676	676 640	640 620	36 20	1,2						0 .03	40 60		
P-11	27+00	106	692	692 680 640	680 640 620	12 40 20	1,2 1,2 3	3:1	1.3			16	.05 .1 .05	10 30 60	1.3	
S-11	27+10	120	678	678 640	640 620	38 20	1,2 3						0 .04	40 60		
P-12	27+20	106	692	692	640	52										ABANDON
S-12	27+30	125	673	673 640	640 620	33 20	1,2 3						0 .06	40 60		
P-13	27+40	129	669	669 640	640 620	29 20	2 3	3:1	0.6			6	.14 .2	30 60	0.6	
S-13	27+50	131	667	667 640	640 620	27 20							0 .02	40 60		
P-14	27+60	90	708	708	686	22										ABANDON
S-14	27+70	120	678	678 640	640 620	38 20							.06 .04	40 60		

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
P-15	27+80	93	705	705 640	640 620	65 20	2	4:1 1:1	1.0 25.0			30	.5 .4	30 60	26.0	STAB SND
S-15	27+90	134	664	664 640	640 620	24 20							0 .04	40 60		
P-16	28+00	132	666	666 640	640 620	26 20	2 3	4:1	2.5			5	.72 .05	30 60		
S-16	28+10	133	665	665 640	640 625	25 15	2 3	4:1	1.0			30	0 .04	40 60		
P-17X	28+20	129	669	669 640	640 620	29 20	2 3	4:1	0.5			5	.08 .14	40 50	0.5	
S-17	28+30	133	665	665 640	640 620	25 20	2 3						.01 .06	40 60		
P-18	28+40	133	665	665 640	640 620	25 20	2 3	4:1	0.6			5	.07 .04	30 60	0.6	
S-18	28+50	132	666	666 640	640 620	26 20	2 3	3:1 3:1	2.3 4.8			30 50	.52 1.2	40 60	7.1	
P-19	28+60	131	667	667 640	640 620	27 20	2 3	4:1 3:1	0.2 3.1			5 60	.22 .74	30 60	3.3	
S-19	28+70	125	673	673 640	640 620	33 20	2 3	3:1 3:1	1.7 2.9			30 50	.72 .20	40 60	4.6	
P-20	28+80	131	667	667 640 640 640	640 620 620 620	27 20 20 20	1,2 3	4:1 3:1 2:1 1:1	1.4 4.9 11.0 0.7			5 60 20 30	.92 2.7	30 60	18.0	
S-20	28+90	118	685	685 640	640 620	45 20	1,2 3	3:1 3:1	3.5 3.6			30 60	.9 .1	40 50	7.1	

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
P-21	29+00	125	673	673	640	33	1,2	4:1	0.6			10	.14	15		
				640	620	20	3	3:1	2.8			60	.58	60	3.4	
S-21	29+10	117	681	681	640	41	1,2	3:1	0.5			10	1.12	40		
				681	640	41		2:1	4.2			10			4.7	
				640	620	20	3		TIGT				.04	60		
P-22	29+20	115	683	683	640	43	1,2	4:1	0.9			15	.24	30		
				640	620	20		3:1	1.8			60	.16	60	2.7	
S-22X	29+30	115	683	683	620	63		4:1	5.3			30	.48	30	5.3	PACK @TH
P-23	29+40	112	686	686	640	46	1,2	4:1	3.5			15	.94	30		
				640	620	20	3	2:1	15.0			4	2.38	0		
				640	620	20		1:1	15.3			30				
S-23	29+50	110	688	688	640	48	1,2	3:1	8.0			27	1.9	30		
				688	640	48	1,2	2:1	20.0			19	.5	30		
				688	640	48	1,2	1:1	40.0			30				
				688	640	48	1,2	.6:1	11.4			30				
				640	620	20	3	3:1	30.0			50	2.52	30		
				640	620	20	3	2:1	40.0			32				
				640	620	20	3	1.5:1	48.0			26				
				640	620	20	3	1:1	41.3			25				
P-24	29+60	112	686	686	640	46	1,2	4:1	7.6			15	1.26	30		
				686	640	46	1,2	3:1	16.0			25				
				686	640	46	1,2	2:1	52.0			25				
				686	640	46	1,2	1:1	22.7			10				
				640	620	20	3	3:1	30.0			20	2.24	30		
				640	620	20		2:1	6.6			55			134.9	
S-24	29+70	107	691	691	640	51	1,2	3:1	19.0			30	.2	40		
				691	640	51		2:1	5.0			20				
				691	640	51		1:1	10.0			10				
				691	640	51		.6:1	22.7			5				
				640	620	20	3	3:1	0.3			60	2.04	15	48.0	

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
P-25	29+80	112	686	686	640	46	1,2	3:1	10.2			0	2.7	0		
				686	640	46	1,2	2:1	40.0			0				
				686	640	46	1,2	1:1	20.0			0				
				686	640	46	1,2	.6:1	68.0			0	2.9	0		
				686	640	46	1,2	S-1	20.0	20	20	0				
				686	640	46	1,2	S-2	12.0	12	24	0				
				686	640	46	1,2	S-3	32.0	32	96	0				
				640	637	3	3	2:1	20.0				3.86	0		L.C.
				640	637	3	3	1:1	50.0							
				640	637	3	3	.6:1	30.0							
				640	637	3	3	S-1	2.0	2	2					
				637	620	17	3	1:1	111							
				637	620	17	3	.75:1	10.0						421.3	
S-25	29+90	102	696	696	670	26	1	3:1	3.3			5	.42	20		
				670	640	30	2	3:1	25.6			23	2.6	32		
				670	640	30	2	2:1	40.0			15	.04	40		
				670	640	30	2	1:1	24.0			10				
				640	620	20	3	3:1	46.4			60	2.52	30		
				640	620	20	3	2:1	40.0			16				
				640	620	20	3	1.5:1	48.0			14				
				640	620	20	3	1:1	100			20				
				640	620	20	3	.75:1	38.0			10			365.3	
P-26	30+00	109	689	689	640	49	1,2	1:1	28.6			10	4.8	0		
				689	640	49	1,2	.6:1	30.0			6				
				689	640	49	1,2	1:1	0.5			10				
				640	620	20	3	3:1	30.0			60	0.7	60		
				640	620	20	3	2:1	60.0			30				
				640	620	20	3	1:1	26.7			30			34.8	
S-26	30+10	102	798	696	670	26	1		TIGT				.06	20		
				670	640	30	2	3:1	4.5			30	0.8	40		
				640	620	20	3	3:1	24.8			60	1.14	60		
				640	620	20	3	2:1	64.0			28				
				640	620	20	3	1.5:1	48.0			20				
				640	620	20	3	1:1	23.7			30			165.0	

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
P-27X	30+20	102	696	696	620	76	123	3:1	20.0			30				PACK@128
				696	620	76	123	2:1	10.0			27				
				696	620	76	123	1:1	0.7			10				
				696	620	76	123	3:1	0.3			5			31.0	PACK @TH
S-27	30+30	98	700	700	670	30	1		TIGT				.08	20		
				670	640	30	2	3:1	33.5			30	1.74	40		
				670	640	30	2	2:1	4.0			25				
				640	620	20	3	3:1	12.8			60	1.0	60	50.3	
P-28	30+40	98	700	700	670	30	1	3:1	1.5			5	.16	20		
				670	640	30	2	1:1	22.6			10	3.48	0		
				640	620	20	3	3:1	10.7			60	1.2	60		
S-28	30+50	92	706	706	670	36	1		TIGT				.06	20	34.8	
				670	640	30	2	2:1	52.0			20	.08	40		
				670	640	30	2	1.5:1	57.3			17				
				640	620	20	3	3:1	22.2			60	2.1	60		
				640	620	20	3	2:1	20.3			45			151.8	
P-29	30+60	93	705	705	670	35	1	3:1	0.8			5	.16	20		
				670	640	30	2	2:1	40.0			10	0	3.52		
				670	640	30	2	1:1	25.7			10				
				640	620	20	3	3:1	24.3			45	1.66	60		
				640	620	20	3	2:1	40.0			40				
				640	620	20	3	1.5:1	32.7			37			163.5	
S-29	30+70	97	701	701	670	31	1	3:1	3.5			5	.22	20		
				670	640	30	2	3:1	7.1			30	.28	40		
				640	620	20	3	3:1	28.6			60	3.7	32	39.2	
P-30	30+80	96	702	702	670	32	1	3:1	1.1			5	1.6	10		
				670	649	21	2	2:1	40.0			5	.22	20		
				670	649	21	2	1:1	40.0			5				
				670	649	21	2	.75:1	14.0			8				
				649	640	9	2	3:1	16.4			30	.22	20		PACK @TH
				649	640	9	2	2:1	40.0			2				
				649	640	9	2	1:1	100			5				

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
P-30	30+80	96	702	649	640	9	2	.75:1	50.0			6				
				649	640	9	2	.6:1	2.0			5				
				640	620	20	3	3:1	2.7			60	2.2	0	306.2	
S-30	30+90	98	700	700	670	30	1	3:1	0.9			5	1.22	20		
				670	640	30	2	3:1	12.9			13	3.9	40		
				670	640	30	2	2:1	32.0			0				
				670	640	30	2	1.5:1	16.0			0				
				670	640	30	2	1:1	13.0			10				
				640	620	20	3	3:1	3.3			60	4.23	24	78.1	
P-31	31+00	97	701	701	670	31	1	3:1	3.9			5	0.9	20		
				670	648	22	2	2:1	11.4			25	2.4	8		
				648	640	8	2	3:1	20.0			13	1.5	40		
				648	640	8	2	2:1	69.4			25				
				640	620	20	3	3:1	14.2			60	4.4	0	118.9	
S-31	31+10	97	701	701	670	31	1		TIGT			T	.04	20		
				670	640	30	2	3:1	0.6			35	3.98	37		CONN S32
				640	620	20	3	3:1	9.6			60	2.6	10	10.2	
P-32X	31+20	93	705	705	620	85	2,3						.1	20		PACK @TH
				673	620	53	2,3	2:1	20.0			2	2.8	0		PACK@125
				673	620	53	2,3	1:1	50.0			9				
				673	620	53	2,3	.6:1	16.4			G				PACK @TH
				705	670	35	2,3		TIGT			T			86.4	
S-32	31+30	95	703	703	670	33	1	3:1	0.3			5	.14	20		
				670	640	30	2	3:1	0.4			35	1.76	40		
				640	620	20	3	3:1	0.4			60	3.9	30	1.1	
P-33	31+40	95	703	703	670	33	1	3:1	0.3			5	.06			
				670	640	30	2	3:1	15.0			5	.96			
				670	640	30	2	2:1	40.0			NP				
				670	640	30	2	1:1	55.3			10				
				640	620	20	3	3:1	20.0			8	2.4	10		
				640	620	20	3	2:1	40.0			10				
				640	620	20	3	1.5:1	58.0			25				

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CNMT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
P-33	31+40	95	703	640	620	20	3	1:1	40.0			30			268.3	
S-33	31+50	94	704	704	670	34	1		TIGT				.16	20		
				670	640	30	2	3:1	16.0			3	.5	40		
				670	640	30	2	2:1	12.8			30				
				640	620	20	3	3:1	23.1			40	2			
				640	620	20	3	2:1	80.0			45				
				640	620	20	3	1.5:1	16.0			37			147.9	
P-34	31+60	93	705	705	670	35	1	3:1	1.4			5	.22	10		
				670	640	30	2	3:1	6.6			30	.94	20		
				640	620	20	3	3:1	3.7			60	2.26	10	11.7	
S-34	31+70	98	700	700	670	30	1		TIGT				.04	20		
				670	640	30	2	3:1	7.4			30	1.12			
				640	620	20	3	3:1	30.0			60	4.3			
				640	620	20	3	2:1	25.2			45			62.6	
P-35	31+80	103	695	695	670	25	1	3:1	0.9			5	.48	20		
				670	640	30	2	3:1	15.3			30	.62	40		
				640	620	20	3	3:1	3.2			60	2.48	10	19.4	
S-35	31+90	103	695	695	670	25	1						3.08	40		
				670	640	30	2	3:1	2.5			30	3.08	40		
				640	620	20	3	2:1	0.2			45	3.2		2.7	
P-36	32+00	104	694	694	670	24	1	3:1	0.7			5	.14	20		
				670	640	30	2	3:1	18.1			15	1.92	10		
				670	640	30	2	2:1	32.0			2				
				670	640	30	2	1:1	74.7			10				
				640	620	20	3	3:1	25.1			30	1.36	10		
				640	620	20	3	2:1	48.0			4				
				640	620	20	3	1.5:1	24.0			2				
				640	620	20	3	1:1	120			30				
				640	620	20	3	.75:1	29.6			10				372.2

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
S-36	32+10	107	691	691	670	21	1		TIGT							
				670	640	30	2	3:1	15.1			23	3.16	0		
				670	640	30	2	2:1	40.0			0				
				670	640	30	2	1.5:1	56.0			5				
				670	640	30	2	1:1	90.0							
				670	640	30	2	.75:1	8.4							
				640	620	20	3	3:1	0.3			60	4.3	30	209.8	
P-37X	32+20	110	688	670	620	50	2,3	1:1	53.6			5				PACK@128
				670	620	50	2,3	.75:1	30.0			6	2.9	2		
				670	620	50	2,3	.6:1	50.0			6				
				670	620	50	2,3	S-1	25.0	25	25	6				4/29/92
				670	620	50	2,3	S-2	10.0	10	10	6				
				670	620	50	2,3	S-3	20.0	20	60	6				
				670	620	50	2,3	2:1	20.0							4/30/92
				670	620	50	2,3	1:1	40.0				2.0	10		
				670	620	50	2,3	.6:1	30.0							
				670	620	50	2,3	S-1	20.0	20	20		.04	20		
				670	620	50	2,3	S-3	20.0	20	60					
				670	620	50	2,3	2:1	20.0			3				
				670	620	50	2,3	1:1	50.0			15				
				670	620	50	2,3	3:1	0.6			5			389.2	
S-37	32+30	112	686	686	640	46	2	3:1	3.7			30				
				686	640	46	2	2:1	17.6			25	1.44	40		
				640	620	20	3	3:1	15.3			60	2.2	6	69.9	
P-38	32+40	119	679	679	670	9	1	3:1	1.1			5	.62	20		
				670	640	30	2	3:1	4.9			30	.72	20		
				640	635	5	3	3:1	20.0			40	2.32	10		L.C.HOLE
				640	635	5	3	2:1	45.0			45				
				635	620	15	3	3:1	20.0			8				
				635	620	15	3	2:1	40.0			0				
				635	620	15	3	1.5:1	40.0			2				
				635	620	15	3	1:1	9.7			30			180.7	
S-38	32+50	118	680	680	640	40	1,2	3:1	22.4			30	2.16	40		
				640	620	20	3	3:1	0.3			60	3.2	8	22.7	

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
P-39	32+60	116	682	682	670	12	1	3:1	1.4			5	1.76	20		
				670	640	30	2	3:1	35.4			30	2.0	10		
				670	640	30	2	2:1	4.6			25				
				640	636	4	3	3:1	25.7			45	2.4	5		
				640	636	4	3	2:1	40.0			32				
				640	636	4	3	1.5:1	24.0			37				
				640	636	4	3	1:1	43.0			30				
				636	620	16	3	3:1	26.3			40	6.24	10		
				636	620	16	3	2:1	40.0			26				
				636	620	16	3	1.5:1	90.0			37				
				636	620	16	3	1:1	1.0			30			331.4	
S-39	32+70	109	689	689	640	49	1,2	3:1	6.6			25	2.36	40		
				640	620	20	3	3:1	11.4			60	3.4	32	18.0	
P-40	32+80	109	689	689	670	19	1	3:1	4.5			5	.58	20		
				670	640	30	2	3:1	5.3			30	1.4	40		
				640	620	20	3	3:1	20.6			60	5.3	20	30.4	
S-40	32+90	111	687	687	670	17	1	3:1	1.4			10	.22	20		
				670	640	30	2	3:1	3.7			30	.54	40	5.6	
				640	620	20	3	3:1	0.5			60	2.74	42		
P-41	33+00	108	690	690	670	20	3	3:1	0.5			5	0.3	20		
				670	640	30	2	3:1	34.9			30	2.88	40		
				670	640	30	2	2.5:1	25.0			30				
				670	640	30	2	2:1	17.4			25				
				640	620	20	3	3:1	0.1			60	4.74	40	77.9	
S-41	33+10	105	693	693	670	23	1	3:1	5.5			10	1.14	20		
				670	640	30	2	3:1	8.9			30	1.22			
				640	620	20	3	3:1	19.4			18	.8	12		
				640	620	20	3	2:1	16.4			45			50.2	
P-42X	33+20	110	688	688	670	18	1	3:1	2.0			10	2.96			PACK@TH
				670	620	50	2,3	3:1	40.0			30				PACK@123
				670	620	50	2,3	2:1	24.2			30			66.2	

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
S-42	33+30	109	689	689	670	19	3	3:1	2.2			10	.48	20		
				670	640	30	2	3:1	22.4			30	1.4	20		
				670	640	30	2	2:1	1.2							
				640	620	20	3	3:1	20.6			0	5.33	18		
				640	620	20	3	2:1	14.4			45			60.8	
P-43X	33+40	107	691	691	670	21	1	3:1	4.8			10	1.1	30	16.5	
				670	620	50	2,3	3:1	6.9			30	1.7	40		PACK@128
S-43	33+50	105	693	693	670	23	1	3:1	1.2			10	2.14	20		
				670	640	30	2	3:1	1.4			30	5.1	40		
				640	620	20	3	3:1	0.8			60	6.24	0	3.4	
P-44	33+60	100	698	698	670	18	1	3:1	7.0			5	0.3	20		
				670	640	30	2	3:1	30.0			15	4.68	40		
				670	640	30	2	2:1	2.6			25				
				640	620	20	3	3:1	24.3			0	6.18	0		
				640	620	20	3	2:1	4.0			45			77.9	
S-44	33+70	102	699	699	670	19	1	3:1	2.7			10	1.32	20		
				670	640	30	2	3:1	0.5			30	2.0	10		
				640	620	20	3	3:1	28.7			60	5.28	0		
				640	620	20	3	2:1	40.0			40				
				640	620	20	3	1.5:1	32.0			40				
				640	620	20	3	1:1	100			28				
				640	620	20	3	.75:1	11.6			10			215.5	
P-45	33+80	98	700	700	670	30	1	3:1	4.0			5	1.4	20		
				670	640	30	2	3:1	0.3			30	4.8	20		
				640	620	20	3	3:1	0.3			60	6.1	0	4.6	
S-45	33+90	96	702	702	670	32	1	3:1	1.5			10	.76	20		
				670	640	30	2	3:1	0.3			30	3.7	30		
				640	620	20	3	3:1	7.9			60	4.8	0	9.7	
P-46	34+00	100	698	698	670	28	1	3:1	1.9			5	1.16	20		
				698	670	28	2	2:1	0.2			30	2.72	20		
				698	670	28	3	3:1	5.1			60	4.87	0	7.2	

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
S-46	34+10	107	691	691	670	21	1	3:1	12.9			10	2.3	20		CONN S47
				670	640	30	2	3:1	3.9			30	2.0	25		
				640	620	20	3	3:1	19.6			60	4.9	60	36.4	
P-47X	34+20	101	697	697	670	27	1	3:1	0.1			5	.28	20		
				670	620	50	2,3	3:1	6.5			40	.36	40	6.6	
S-47	34+30	101	697	697	670	27	1	3:1	0.3			10	1.44	20		
				670	640	30	2	3:1	23.4			15	2.7	40		
				670	640	30	2	2:1	32.0			8				
				670	640	30	2	1.5:1	74.0			15				
				670	640	30	2	1:1	21.7			8				
				640	620	20	3	3:1	0.2			70	4.9	22	151.6	
P-48	34+40	107	691	691	670	21	1	3:1	1.8			5	.46	20		
				670	640	30	2	3:1	30.0			0	3.6	20		
				670	640	30	2	2:1	6.4			25				
				640	620	20	3	3:1	34.9			60	4.7	0		
				640	620	20	2	2:1	28.6			50			101.7	
S-48	34+50	97	701	701	696	5	1	3:1	30.7			0	1.8	20	696.0	L.C.
				701	696	5	1	2:1	40.0			0				
				701	696	5	1	1.5:1	40.0			0				
				701	696	5	1	1:1	33.3			2				
				696	670	26	1	3:1	4.4			10	.42	20		
				670	640	30	2	3:1	36.5			10	1.8	40		
				670	640	30	2	2:1	32.0			20				
				670	640	30	2	1.5:1	59.5			20				
				640	620	20	3	3:1	12.2			60	3.3	22	288.6	
P-49	34+60	100	698	698	670	28	1	3:1	2.2			10	3.62	20		
				670	640	30	2	3:1	5.1			30	5.2	8		
				600	620	20	3	3:1	0.2			60	5.28	0	8.4	
S-49	34+72	101	697	697	670	27	1	3:1	5.4			5	4.36	10		
				670	640	30	2	3:1	1.9			30	1.04	20		
				640	620	20	3	3:1	4.9			60	5.3	60	12.2	

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
P-50	34+80	99	699	699	670	29	1	3:1	3.1			10	1.8			CONN P51
				670	640	30	2	3:1	29.9			0	5.1			SET PACK
				670	640	30	2	2:1	40.0			3				P-51
				670	640	30	2	1.5:1	24.0			5				
				670	640	30	2	1:1	14.3			10				
				640	620	20	3	3:1	26.4			60	5.56	0		
				640	620	20	3	2:1	36.2			50			173.9	
S-50	34+90	101	697	697	670	27	1	3:1	9.4			10	1.56	20		
				670	640	30	2	3:1	23.1			30	3.96	40		
				670	640	30	2	2:1	40.0			25				
				670	640	30	2	1.5:1	21.3			17				
				640	637	3	3	3:1	25.0			45	6.2	5		LC @ 637
				640	637	3	3	2:1	40.0			25				
				640	637	3	3	1.5:1	35.5			20				
				637	620	17	3	3:1	25.1			46	38	30		
				637	620	17	3	2:1	40.0			40				
				637	620	17	3	1.5:1	40.0			35				
				637	620	17	3	1:1	260			35				
				637	620	17	3	.75:1	11.2			20			570.6	
P-51	35+00	101	697	697	670	27	1	3:1	32.9			10	2.88	12		
				697	670	27	1	2:1	48.6			9				
				670	640	30	2	3:1	2.1			30	4.8	2		
				640	620	20	3	3:1	0.0			60	4.14	8	83.6	
S-51	35+10	102	696	696	670	26	1	3:1	29.6			5	5.2	10		
				696	670	26	1	2:1	48.2			5				
				670	640	30	2	3:1	1.2			30	5.8	0		
				640	620	20	3	3:1	25.0			60	.34	60		
				640	620	20	3	2:1	40.6			45			144.6	
P-52	35+20	100	698	698	670	18	1	3:1	15.2			10	1.82	20		
				670	640	30	2	3:1	24.6			0	6.72	40		
				670	640	30	2	2:1	24.0			0				
				670	640	30	2	1.5:1	24.0			0				
				670	640	30	2	1:1	90.0			0				
				670	640	30	2	.75:1	50.0			0				

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
P-52	35+20	100	698	670	640	30	2	.6:1	59.0			2				
				640	620	20	3	3:1	6.5			60	4.14	0	293.3	
S-52	35+30	93	705	705	670	35	1	3:1	5.3			5	2.02	20		
				670	640	30	2	3:1	0.3			30	5.7	10		
				640	620	20	3	3:1	30.0			60	5.42	4		
				640	620	20	3	2:1	40.0			36				
				640	620	20	3	1.5:1	80.0			38				
				640	620	20	3	1:1	287			35			442.8	
P-53	35+40	91	707	707	670	37	1	3:1	19.6			10	1.76	4		
				670	640	30	2	3:1	20.0			2	8.52	20		
				670	640	30	2	2:1	32.0			2				
				670	640	30	2	1.5:1	32.0			2				
				670	640	30	2	1:1	70.0			2				
				670	640	30	2	.75:1	8.4			2				
				640	620	20	3	3:1	2.2			60	5.0	0	207.1	
S-53X	35+50	95	703	703	620	83	123	3:1	3.4			30	4.8	20	3.4	PACK@128 RESET TH
P-54	35+60	96	702	702	670	32	1	3:1	1.5			10	.22	20		
				670	640	30	2	3:1	2.5			30	5.4			
				640	620	20	3	3:1	25.1			30	5.4	0		
				640	620	20	3	2:1	64.0			50				
				640	620	20	3	1.5:1	32.0			37				
				640	620	20	3	1:1	18.0			30			143.1	
S-54	35+70	94	704	704	670	34	1	3:1	12.1			10	1.74	10		
				670	640	30	2	2:1	19.2			30	7.42	30		
				640	620	20	3	3:1	25.0			25	5.3	17		
				640	620	20	3	2:1	48.0			24				
				640	620	20	3	1.5:1	16.0			20				
				640	620	20	3	1:1	21.0			20			141.3	
P-55	35+80	95	703	703	670	33	1	3:1	2.9			10	2.1	20		
				670	640	30	2	3:1	6.1			30	8.08	20		
				640	620	20	3	3:1	17.5			20	5.8	17		

HOLE NO.	STAT.	CASING LENGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	SACK CMNT	CF F/A	C.F. SAND	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
P-55	35+80	95	703	640	620	20	3	2:1	1.6			45			35.3	
S-55	35+90	110	688	688	670	18	1	3:1	3.0			10	2.14	20		
				670	640	30	2	3:1	20.8			18	7.04	10		
				670	640	30	2	2:1	32.0			2				
				670	640	30	2	1.5:1	40.0			4				
				670	640	30	2	1:1	59.0			10				
				640	620	20	3	3:1	16.0			40	4.3	0		BROKE DN
				640	620	20	3	3:1	30.0			40				RESTART
				640	620	20	3	2:1	40.0			40				
				640	620	20	3	1.5:1	56.0			38				
				640	620	20	3	1:1	57.7			35		354.5		
P-56	36+00	102	696	696	670	26	1	3:1	3.1			10	1.16	0		
				670	640	30	2	3:1	37.0			30	7.96	0		
				670	640	30	2	2:1	106			6	5.48	28		
				670	640	30	2	1.5:1	72.2			2				
				670	640	30	2	1:1	180			2				
				670	640	30	2	.75:1	80.0			2				
				670	640	30	2	.6:1	88.0			2				
				670	640	30	2	S-1	25.0	25	25	2				6/9/92
				670	640	30	2	S-3	25.0	25	75	2				
				640	620	20	3	3:1	20.0			5	5.16	10		
				640	620	20	3	2:1	24.0			16				
				640	620	20	3	1.5:1	48.0			20				
				640	620	20	3	1:1	19.3			40			727.2	
TP56X	36+05	101	697	668	620	48	123	3:1	90.2			0	5.5	20		PACK@130
				668	620	48	123	2:1	96.0			0				
				668	620	48	123	1.5:1	144			0				
				668	620	48	123	1:1	320			10				
				668	620	48	123	.75:1	66.8			5	6.5	40		
				640	620	20	3	3:1	10.0			0	5.1	8		PACK@TH
				640	620	20	3	2:1	10.0			30				
				640	620	20	3	1.5:1	128			25			865.3	

RED ROCK DAM
TERTIARY HOLE COMPENDEMIUM

HOLE NO.	STATION	CASING LGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	(CF) SACKS CEMNT	LBS MICR	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
TS-22	29+35	113	685	685	640	45	1,2	3:1	2.2		30	.28	40		
				640	620	20	3	3:1	23.8	1571	60	1.48	60	26	MICRO
TP-23	29+45	110	688	688	640	48	1,2	3:1	1.8		30	.64	40		
				640	620	20	3	3:1	20.0	1320	45	1.4	60		MICRO
				640	620	20	3	2:1	16.7	1100	45				MICRO
				640	620	20	3	1:1	5.1	334	10			43.6	MICRO
TS-23	29+55	111	687	687	640	47	1,2	3:1	2.4		30	1.7	40		
				640	620	20	3	3:1	19.1	1258	45	1.4	60		MICRO
				640	620	20	3	2:1	16.7	1100	45				MICRO
				640	620	20	3	1:1	6.9	453	30			45.1	MICRO
TP-24	29+65	110	688	688	640	48	1,2	3:1	1.6		30	1.6	40		
				640	620	20	3	3:1	3.7		60	2.2	20	5.3	
TS-24	29+75	106	692	692	670	22	1	---	TIGHT		--	.02	20		
				670	640	30	2	3:1	0.3		30	.88	40		
				640	620	20	3	3:1	1.2		60	2.2	14	1.5	
TP25X	29+85	102	696	696	665	31	1	3:1	25		15	2.5	10		L.C. @ 665
				665	620	45	2,3	3:1	25.3		30	3.8	20		
				665	620	45	2,3	2:1	32		35				
				665	620	45	2,3	1.5:1	40		30				
				665	620	45	2,3	1:1	35		20			157.3	
TS-25	29+95	100	698	698	640	58	1,2	3:1	0			.02	20		
				698	640	58	3	3:1	25.1						
				698	640	58	3	2:1	40						
				698	640	58	3	1.5:1	40						
				698	640	58	3	1:1	11.7					116.8	
TP-26	30+05	104	694	694	640	54	1,2	3:1	9.9		30	1.8	40		
				640	620	20	3	3:1	15.2		60	2.3	45	25.1	
TS-26	30+15	102	696	696	640	56	1,2	3:1	4.5		30	.84	40		
				640	620	20	3	3:1	20		60	.82	40		

HOLE NO.	STATION	CASING LGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	(CF) SACKS CEMNT	LBS MICR	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
TS-26	30+15	102	696	640	620	20	3	2:1	0.9		45			25.1	
TP-27	30+25	101	697	697	640	57	1,2	3:1	5.0		30	.02	40		
				640	620	20	3	3:1	1.7		60	.74	45	6.7	
TS-27	30+35	101	697	697	670	27	1					TGHT	20		
				670	640	30	2					TGHT	40		
				640	620	20	3	3:1	3.8		60	2.3	24	3.8	
TP-28	30+45	100	698	698	640	58	1,2	3:1		1320	15	TGHT	20		*20 CF MICRO
				698	640	58	1,2	2:1		2200	20				33.3CF MCR 66
				698	640	58	1,2	1.5:1		2200	20				33.3CF MCR 66
				698	640	58	1,2	1:1		3520	10	TGHT	40		53.3CF MCR 66
				698	640	58	1,2	.8:1		176	10				2.67CF MCR 66
				640	620	20	3	2:1		1918	30	4	30		29.1CF MCR 66
				640	620	20	3	1:1		3080	30			218.4	46.7CF MCR 66
TS-28	30+55	95	703	703	640	63	1,2	.8:1		176	10	.08	40		2.7 CF MICRO
				640	620	20	3	3:1		1100	30	2.8	40		16.7 CF
				640	620	20	3	2:1		2041	30			50.3	30.9 CF
TP-29	30+65	95	703	703	640	63	1,2	---				TGHT	40		
				640	620	20	3	3:1	15.3		60	1.8	44	15.3	
TS-29	30+75	95	703	703	670	33	1	3:1	2.2		5	.4	20		
				670	640	30	2	3:1	30		30	3.8	30		CONN. TP-30
				670	640	30	2	2:1	7.8		25				SET PACK TP30
				640	620	20	3	3:1	3.2		60	2.8	24	43.2	
TP-30	30+85	98	700	700	670	30	1	3:1	1.1		10	.34	20		
				670	640	30	2	3:1	0.3		30	3.6	25		
				640	620	20	3	3:1	13.1		60	2	29		
				640	620	20	3	2:1	0.8		45			15.3	
TS-30	30+85	97	701	701	670	31	1	3:1	1.4		10	0.6	20		
				670	640	30	2	3:1	2.5		30	0.8	40		
				640	620	20	3	3:1	22		60	2.4	42	25.9	

HOLE NO.	STATION	CASING LGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	(CF) SACKS CEMNT	LBS MICR	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
TP-31	31+05	97	701	701	670	31	1	3:1	0.9		10	1.2	20		
				670	640	30	2	3:1		211 2	30	54	40		3.2 CF MICRO2
				640	620	20	3	3:1	23		60	2.4	60		
				640	620	20	3	2:1	24		20				
				640	620	20	3	1:1	30.7		30			81.8	
TS-31	31+15	97	701	701	670	31	1	3:1	4.3		10	.42	20		
				670	640	30	2	3:1		404 8	30	1.8	40		6.1 CF MCR Z2
				640	620	20	3	3:1	1		60	0	60	11.4	
TP-32	31+25	97	701	701	670	31	1	3:1	4.4		10	1.7	20		
				670	640	30	2	3:1	17.9			1.3	20		
				640	620	20	3	3:1		88	45	.62	60		1.3 CF MICRO
				640	620	20	3	3:1	14		60				
				640	620	20	3	2:1	11.6		45			49.2	
TS-32	31+35	95	703	703	670	33	1	3:1	0.6		10	2.4	20		
				670	640	30	2	3:1	1		30	7.6	0		LOST CIRC Z 2
				670	640	30	2	3:1		1100	0				16.7 CF MICRO
				670	640	30	2	2:1		501 6	25				7.6 CF MICRO
				670	640	30	2	3:1		140 8	45				2.1 CF MICRO
				640	620	20	3	3:1	8		60	3.7	60	36	
TP-33	31+45	95	703	703	670	33	1	3:1	2		10	.24	20		
				670	640	30	2	3:1	0.3		30	5.5	0		
				640	637	3	2	3:1		272 8	30	7.1	0		4.1 CF MICR
															LOST CIRC Z2
				637	620	17	3	3:1	1.3		60	.63	60	7.7	
TS-33	31+55	95	703	703	640	63	1,2	3:1	4.2		30	2.7	40		
				640	620	20	3	3:1	15.8		60	.49	20	20	
TP-34	31+65	98	700	700	670	30	1	3:1	1.2		30	.45	20		
				670	640	30	2	3:1	3.4		30	.74	40		
				640	620	20	3	3:1	8.7		60	.33	28	13.3	
TS-34	31+75	113	685	685	670	15	1	3:1	1.3		10	.41	20		
				670	640	30	2	3:1	9.3		30	.8	40		

HOLE NO.	STATION	CASING LGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	(CF) SACKS CEMNT	LBS MICR	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
TS-34	31+75	113	685	640	620	20	3	3:1	0.6		60	.57	0	11.2	
TP-35	31+85	103	695	695	670	25	1	3:1	1.2		10	.87	20		
				670	640	30	2	3:1	0.1		30	1.6	40		
				640	620	20	3	3:1	9.4		45	.42	0		CONN. TP-36
				640	620	20	3	2:1	9.2		45			19.9	
TS-35	31+95	104	694	694	670	24	1	3:1	1.0		19	.47	20		
				670	640	30	2	3:1	25		30	1.96	40		
				670	640	30	2	2:1	22.4		25				
				640	620	20	3	3:1	4.3		60	.57	0	52.7	
TP-36	32+05	105	693	693	670	23	1	3:1	1.0		10	.26	20		
				670	640	30	2	3:1	5.1		30	1.96	34		
				640	620	20	3	2:1	0.6		45	0.4	0	6.7	CONN. TP-35
TS36X	32+15	110	688	688	670	--	1	.75:1	10		30	4.5	20		PACK @ T.H.
				670	620	68	2,3	3:1	25		25	4.5	30		PACK @ 130'
				670	620	68	2,3	2:1	32		10				
				670	620	68	2,3	1.5:1	40		8				
				670	620	68	2,3	1:1	150		15			257	
TP-37	32+25	113	685	685	670	15	1	3:1	5.7		5	0.8	20		
				670	640	30	2	3:1	0.3		30	2.3	8		
				640	620	20	3	3:1	9.7		60	.42	20	15.7	
TS-37	32+35	113	685	685	670	15	1	3:1	1.2		5	1.2	20		
				670	640	30	2	3:1	0.1		30	3.7	20		
				640	620	20	3	3:1	17.8		60	.57	0	19.1	
TP-38	32+45	117	681	681	670	11	1	3:1	3.4		5	2.1	20		
				670	640	30	2	3:1	3.2		30	3.7	0		
				670	640	30	2	3:1	10.2		30	.45	0		L.C.C. 148'
				670	640	30	2	2:1	1.2		25				REGROUT ZONE
				640	620	20	3	3:1	0.2		60	.57	0	18.2	
TS-38	32+55	113	685	685	670	15	1	3:1	0.7		5	.5	20		
				670	640	30	2	3:1	7.7		30	4.9	20		

HOLE NO.	STATION	CASING LGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	(CF) SACKS CEMNT	LBS MICR	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
TS-38	32+55	113	685	640	620	20	3	3:1	1.3		60	.01	60	9.2	
TP-39	32+65	105	693	693	670	23	1	3:1	1.2		5	.45	20		
				670	640	30	2	3:1	0.3		30	2.7	40		
				640	620	20	3	3:1	0.2		60	0	60	1.7	
TS-39	32+75	106	692	692	670	22	1,2	3:1	19.4		30	.82	20		
				692	670	22	1,2	2:1	34		25	1.6	40		
				670	640	30	2	3:1		356[4]	30	1.1	40		5.4 RECHECK
				640	620	20	3	3:1	10.5		60	.48	20	69.3	
TP-40	32+85	104	694	694	640	54	1,2	3:1		409	30	.84	40		6.2 CF MICRO
				640	620	20	3	3:1	3		60	2.2	38	9.2	
TS-40	32+95	108	690	690	670	20	1	3:1		470[8]	10	.42	10		7.1 CF MICRO
				670	640	30	2	3:1	20.8		30	.09	40		
				640	620	20	3	3:1	0.3		60	3.0	42	28.2	
TP-41	33+05	109	689	689	670	19	1	3:1	0.6		10	5.6	10		
				670	640	30	2	3:1	9.2		30	.33	40		
				670	640	30	2	2:1	27.1		25				
				640	620	20	3	3:1	8.1		60	1.2	60	45.1	
TS-41	33+15	106	692	692	670	22	1	3:1		2807	10	.76	20		42.5 CF MICRO
				692	670	22	1	2:1		136	5				2 CF MICRO
				670	640	30	2	3:1	5.0		30	0	40		
				640	620	20	3	3:1	TIGHT			0	60	49.5	TIGHT BACKFIL
TP-42	33+25	108	690	690	670	20	1	3:1		136[4]	10	.74	10		2.1 CF MICRO
				670	640	30	2	3:1	1.8		30	.02	40		CONN TS-41
				640	620	20	3	3:1	26.6		50	.12	60		
				640	620	20	3	2:1	22.8		45			53.3	
TS-42	33+35	108	690	690	670	20	1	3:1	6.3		5	.8	20		
				670	640	30	2	3:1	23.1		30	.34	0		
				670	640	30	2	2:1	8.0		25	.43	10		
				640	620	20	3	3:1	24.2		60			61.6	

HOLE NO.	STATION	CASING LGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	(CF) SACKS CEMNT	LBS MICR	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
TP-43	33+45	105	693	693	670	23	1	3:1	1.7		5	.94	20		
				670	640	30	2	3:1	0.4		30	.48	0		
				640	620	20	3	3:1	15		60	5.4	6		CONN. TS-43
				640	620	20	3	2:1	11.6		45			28.7	
TS-43	33+55	108	690	690	670	20	1	3:1	1.5		5	.22	20		
				670	640	30	2	3:1	0.3		30	.48	0		
				640	620	20	3	3:1	0.2		60	6.7	20	2.0	
TP-44	33+65	104	694	694	670	24	1	3:1	7.6		5	3.2	20		
				670	640	30	2	3:1	0		30	.51	40		
				640	620	20	3	3:1	0.9		60	.75	10	8.5	
TS-44	33+75	102	696	696	670	26	1	3:1	0.2		5	2.1	20		
				670	640	30	2	3:1	0.6		30	.45	0		
				640	620	20	3	3:1	4.2		60	5.3	8		
				640	620	20	3	2:1	1.6		45			6.6	
TP-45	33+85	98	700	700	670	30	1	3:1	0.5		5	.16	20		
				670	640	30	2	3:1	0.9		30	.48	0		
				640	620	20	3	3:1	28		66	0.4	13	29.4	CONN TO TP-44
TS-45	33+95	98	700	700	670	30	1	3:1	1.3		5	.16	20		
				670	640	30	2	3:1	2.9		30	.48	0		
				640	620	20	3	3:1	24.4		60	.4	13		
				640	620	20	3	2:1	10.8		45			39.4	
TS-46	34+15	104	694	694	670	24	1	3:1	0.8		5	.32	20		
				670	640	30	2	3:1	26.1		30	.44	28		
				670	640	30	2	2:1	42.4		25				
				640	620	20	3	3:1	25.4		20	.56	0		
				640	620	20	3	2:1	12		45			106.7	
TP-47	34+25	101	697	697	670	27	1	3:1	1.6		5	1.9	20		
				670	640	30	2	3:1	5.2		30	.13	40		
				640	620	20	3	3:1	8.9		60	5.6	30	15.7	

HOLE NO.	STATION	CASING LGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	(CF) SACKS CEMNT	LBS MICR	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
TS-47	34+35	103	695	695	670	25	1	3:1	0.3		5	.34	20		
				670	640	30	2	3:1	18.5		30	.48	40		
				640	620	20	3	2:1	0.2		60	0	60	19	
TP-48	34+45	101	697	697	670	27	1	3:1	0.4		5	.12	20		
				670	640	30	2	3:1	0.3		30	.32	40		
				640	620	20	3	3:1	1.2		60			1.9	
TS-48	34+55	98	700	700	670	30	1	3:1		57 2	5	1.7	20		.87 CF MICRO
				670	640	30	2	3:1	9.1		30	.25	40		
				640	620	20	3	3:1	2.0		60	0	60	12	
TP-49	34+65	98	700	700	670	30	1	3:1		1168	10	1.3	20		17.7 CF MICRO
				670	640	30	2	3:1	0.3		30	.45	40		
				640	620	20	3	.75:1	1.2		20	4.3	20	19.2	CN QS48A,B Z2
TS-49	34+75	99	699	699	670	29	1	3:1		132	5	.45	20		2 CF MICRO
				670	640	30	2	3:1	0.3		30	.26	40		
				640	620	20	3	3:1	0.9		60	3.1	50	3.2	
TP-50	34+85	101	697	697	670	27	1	3:1		0	5	1.02	20		MICRO
				670	640	30	2	3:1	3.1		30	.08	40		
				640	620	20	3	3:1	0.2		60	0	60	3.3	
TS-50	34+95	103	695	695	670	25	1	3:1	2.4		5	1.2	20		
				670	640	30	2			611 6	30	3.4	40		9.3 CF MICRO
				640	620	20	3	21.3			60	.46	0	33	CON TP51,TS51
TP-51	35+05	103	695	695	670	25	1	3:1	3.3		5	.4	10		
				670	640	30	2	3:1		8.8	30	0	20		.13 CF MICRO
				640	620	20	3	3:1	0.6		60	.55	60	4	
TS-51	35+15	103	695	695	670	25	1	3:1	0.8		5	2.3	14		
				670	640	30	2	3:1	20		30	4	16		
				670	640	30	2	2:1	4.6		25	.57	20		
				640	620	20	3	3:1	0.2		60			25.6	CON TS50,TP51

HOLE NO.	STATION	CASING LGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	(CF) SACKS CEMNT	LBS MICR	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
TP-52	35+25	105	693	693	670	23	1	3:1	2.3		5	.88	20		
				670	640	30	2	3:1	0.8		25	1.7	40		CONN TS-51
				640	620	20	3	3:1	29		60	.37	35		
				640	620	20	3	2:1	9		45	2		41.1	
TS-52	35+35	96	702	702	670	32	1	3:1	3.9		5	2.4	20		
				670	640	30	2	3:1	30.6		30	4.4	0		
				670	640	30	2	2:1	11		25				
				640	620	20	3	3:1	3.9		60	4.4	0	49.4	
TP-53	35+45	95	703	703	670	33	1	3:1	2.4		5				
				670	640	30	2	3:1	25		30				
				670	640	30	2	2:1	56		25				
				670	640	30	2	1.5:1	48		0				
				670	640	30	2	1:1	150		0				
				670	640	30	2	.75:1	10		0				
				670	640	30	2	.6:1	14.6		10				
				640	620	20	3	3:1	14		60				
				640	620	20	3	2:1	48		45				
				640	620	20	3	1:1	55.7		30			423.7	
TS-53	35+55	95	703	703	670	33	1	3:1	3.7		5	2.9	20		
				670	640	30	2	3:1	25		30	1.4	10		
				670	640	30	2	2:1	1.8		25				
				670	640	30	2	3:1	25		25				L.C. @ 141'
				670	640	30	2	2:1	33.6		25				
				640	620	20	3	3:1	0.5		60				
TP-54	35+65	95	703	703	670	33	1	3:1	0.6		5	2.5	20		
				670	640	30	2	3:1	2.8		30	0.3	40		
				640	620	20	3	3:1	18.3		60	.46	30		
				640	620	20	3	2:1	41.6		45			63.3	
TS-54	35+75	95	703	703	670	33	1	3:1	0.7		5	4.6	20		
				670	640	30	2	3:1	0.3		30	5.6	0		
				640	620	20	3	3:1	26.9		60	3.0	10		
				640	620	20	3	2:1	48		45				
				640	620	20	3	1:1	11		30			86.9	

HOLE NO.	STATION	CASING LGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	(CF) SACKS CEMNT	LBS MICR	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
TP-55	35+85	108	690	690	670	20	1	3:1	13.1		5	3.8	20		
				670	640	30	2	3:1	0.1		30	2.8	10		
				640	620	20	3	3:1	1.5		60	.43	15	14.7	
TS-55	35+95	98	700	700	670	30	1	3:1	4.8		5	3	20		
				670	640	30	2	3:1	28		30	4.6	10		
				670	640	30	2	2:1	56		25				
				670	640	30	2	1.5:1	16		0				
				670	640	30	2	1:1	200.4		10				
				640	620	20	3	3:1	22.4		60	5.5	30		
				640	620	20	3	2:1	32		45			359.6	

RED ROCK DAM
QUARTERNARY COMPENDEMIUM

HOLE NO.	STATION	CASING LGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	(CF) SACKS CEMNT	LBS MICR	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
QS23AX	29+52.5	108	690	690	620	70	123	3:1	0.6		5	2.8	32		PACK @ T.H.
				690	620	70	123	3:1	21.7		30			22.3	PACK @ 130'
QP25A	29+82.5	104	694	694	640	54	1,2	3:1	13.9		30	.1	20		
				694	640	54	1,2	2:1	16		25	2.1	40		
				640	620	20	3	3:1	15		60	4.2	42		
				640	620	20	3	2:1	11		45			55.9	
QP25B	29+87.5	103	695	695	640	55	1,2	3:1	6.1		30	1.3	40		
				695	640	55	1,2	2:1	0.2		60	3.4	40	6.3	
QP28A	30+42.5	98	700	700	640	60	1,2	3:1	10.3		30	.76	40		
				640	620	20	3	2:1	7.2		45	1.4	60	17.5	
QP28BX	30+47.5	93	705	705	624	81	123	3:1	5.0		5	1.1	40		PACK @ T.H.
				705	624	81	123	3:1	1.6		30	.53	20	6.6	PACK @ 130'
QS36A	32+17	111	687	687	670	17	1	---	TIGHT		--	.08	20		
				670	640	30	2	3:1	44.9		30	2.5	8		
				670	640	30	2	2:1	32		25	.57	0		
				670	640	30	2	1:1	20		10				
				640	620	20	3	3:1	2.7		60			99.6	
QS48A	34+52.5	98	700	700	670	30	1	3:1	0.7		5	1.6	20		
				670	640	30	2	3:1	11.3		45	2.4	12		
				670	640	30	2	2:1	150		10				
				670	640	30	2	.75:1	2.8		5				
				640	620	20	3	3:1	15		60	4.5	4		
				640	620	20	3	2:1	7.6		45			187.4	
QS48B	34+57.5	98	700	700	670	30	1	3:1	1.6		5	1.4	20		
				670	640	30	2	3:1	0.8		30	2.7	10		
				640	620	20	3	3:1	0.2			3.7	6	2.6	
QP53A	35+42.5	96	702	702	670	32	1	3:1	0.4		5	4.8	20		
				670	640	30	2	3:1	18.4		30				CONN QP53B

HOLE NO.	STATION	CASING LGTH	EL. B.C.	DRILLING FROM	DRILLING TO	L.F. DRILL	ZONE	MIX	(CF) SACKS CEMNT	LBS MICR	GROUT PRESS	PRESS TEST CFM	PRESS TEST PRESS	TOTAL SACKS	COMMENTS
QP53A	35+42.5	96	702	640	620	20	3	2:1	0.2		45	6.1	0	19	
QP53B	35+47.5	95	703	703	670	33	1	3:1	9.9		5	6.0	20		
				670	640	30	2	3:1	0		30	.05	20		CONN QP53A
				640	620	20	3	3:1	6.6		60	7.8	0		
				640	620	20	3	2:1	8.8		45				
QS55B	35+92.5	108	690	690	640	50	1,2	3:1	2.7		30	0	20		
				690	640	50	1,2	2:1	32		20				
				690	640	50	1,2	1:1	37.6		10				
				640	620	20	3	2:1	1.2		45	6.1	0	73.5	
QS55B	35+97.5	100	698	698	640	58	1,2	1:1	0		10				CONN QS55A
				640	620	20	3	3:1	15		60	6.6	30		
				640	620	20	3	2:1	0.2		45			15.2	
QP56A	36+02	102	696	696	640	56	1,2	3:1	25		30	3.3	40		
				696	640	56	1,2	2:1	32		0				
				696	640	56	1,2	1.5:1	32		2				
				696	640	56	1,2	1:1	150		6				
				696	640	56	1,2	.75:1	50		0				
				696	640	56	1,2	.6:1	54.6		5				
				640	620	20	3	3:1	26.4		30	.43	30		
				640	620	20	3	2:1	18.4		45			388.4	

Table A-2

Remedial Grouting Stage I
(Areas of Significant Takes)

TABLE A-2

REMEDIAL GROUTING STAGE I
1991-1992
(AREAS OF SIGNIFICANT TAKES)

This table shows grout holes, total take of cement in cubic feet, lineal feet drilled and take per lineal foot.

Primary holes were drilled and grouted first and are designated P. Secondary holes are designated S. Tertiary holes are designated T, TP, and TS. Quaternary holes are designated Q, QP, and QS.

The intent of this table is to illustrate grout holes that had significant grout takes per linear foot drilled and the subsequent or adjacent grout hole which shows the stage being sealed by comparative low takes per lineal foot.

In general, one cubic foot per foot or less is considered to be on the low side for grouting this type of formation.

Hole	Station	Lin. ft drilled	Total Take (cu ft)	Take per lin. ft.
TP-56X*	36+05	77	805.2(cavity)	10.5
QP-56A*	36+02	76	388.4(cavity)	5.1
P-56*	36+00	76	727.2(cavity)	9.6
QS-55B	35+97.5	78	15.2	0.19
QS-55A	35+92.5	70	73.5	1.05
TS-55	35+95	80	359.6	4.5
S-55	35+90	68	354.5	5.2
QP-53B	35+47.5	83	25.3	0.8
TP-53	35+45	83	423.7	5.1
QP-53A	35+42.5	82	190.0	0.23
P-52	35+20	78	293.3	3.76
TP-52	35+25	73	41.1	0.56
S-52	35+30	85	442.8	5.2
TS-52	35+35	82	49.4	0.6
QS-48B	34+57.5	80	2.6	0.03
QS-48A	34+52.5	80	186.6	2.33
S-48	34+50	81	288.9	3.6
TS-38	32+55	65	9.2	0.14
P-39	32+60	62	288.4	4.7
TP-39	32+65	73	1.7	0.02
QS-36(A)	32+17	67	99.6	1.4
P-37X	32+20	68	369.2	5.4
TP-37	32+25	65	15.7	0.24
TP-A36	32+15	63	6.7	0.10
P-36	32+00	74	371.4	5.0
TS-35	31+95	64	254.3	3.9

Hole	Station	Lin. ft drilled	Total Take (cu ft)	Take per lin. ft.
S-35	31+90	75	2.7	0.04
P-33	31+40	83	268.5	3.2
TP-33	31+45	86	7.7	0.09
TS-32	31+35	80.3	35.4	0.44
TS-29	30+75	83	43.2	0.52
P-30	30+30	82	306.2	3.7
TP-30	30+85	80	15.3	0.19
QP-28BX	30+47.5	85	6.6	0.08
TP-28	30+45	78	218.7	2.8
QP-28A	30+42.5	70	17.5	0.25
S-25	29+90	76	365.3	4.8
QP-25B	29+87.5	75	6.3	0.08
TP-25X	29+85	81	157.0	1.9
QP-25A	29+82.5	74	67.9	0.91
P-25	29+80	87	660.0	7.6
QS-23AX	29+52.5	70	22.3	0.32
S-23	29+50	68	238.7	3.5

* This reach will be overlapped ±50 feet on Stage II grouting.

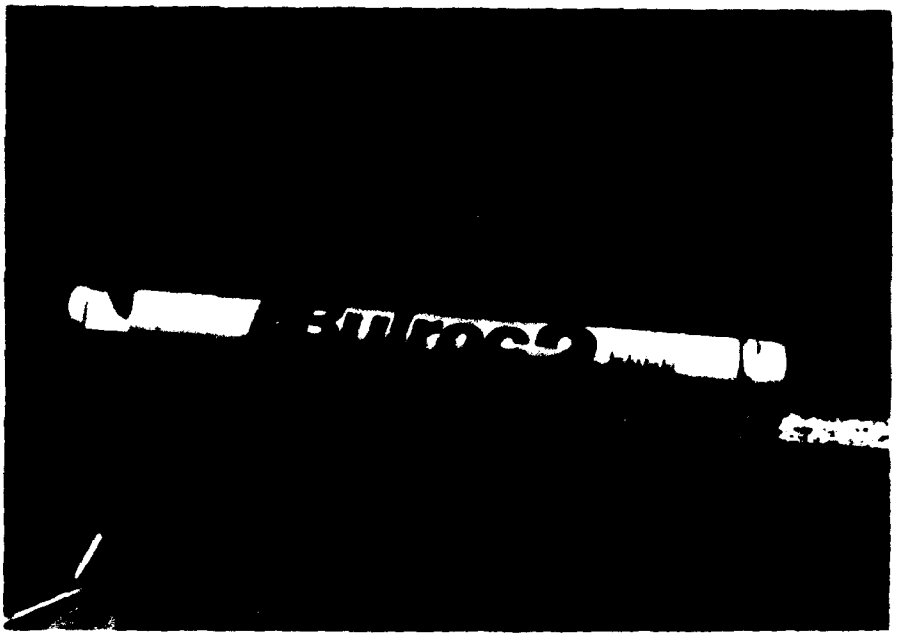
Appendix B

Photographs

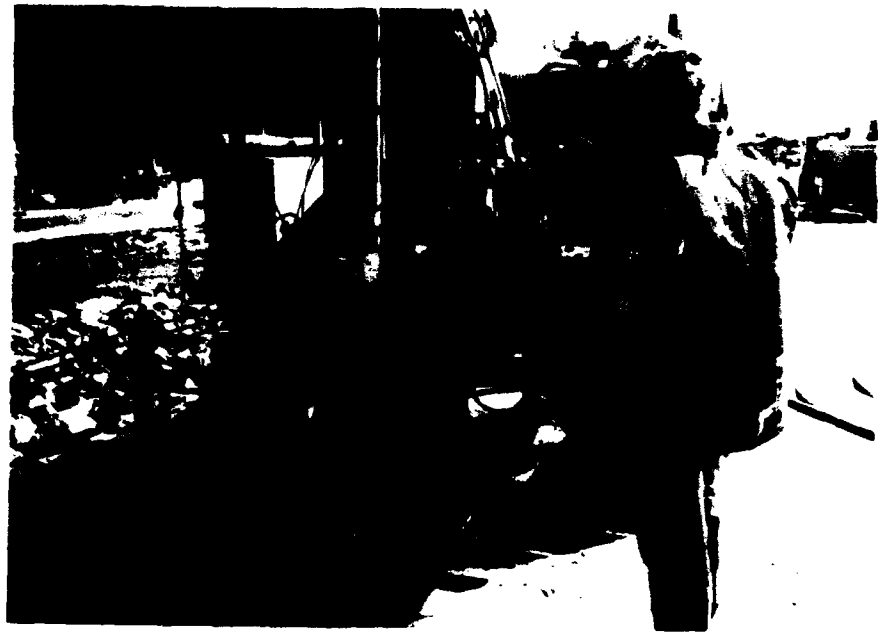
(Photo 1) Georex T500 S/S Auger Drill (drilling overburden with fishtail bit on flight augers)

(Photo 2) Chicago Pneumatic CP350 Rotary Drill (drilling overburden)

(Photo 3) CP 350 Rotary Drill, taking sample cutting

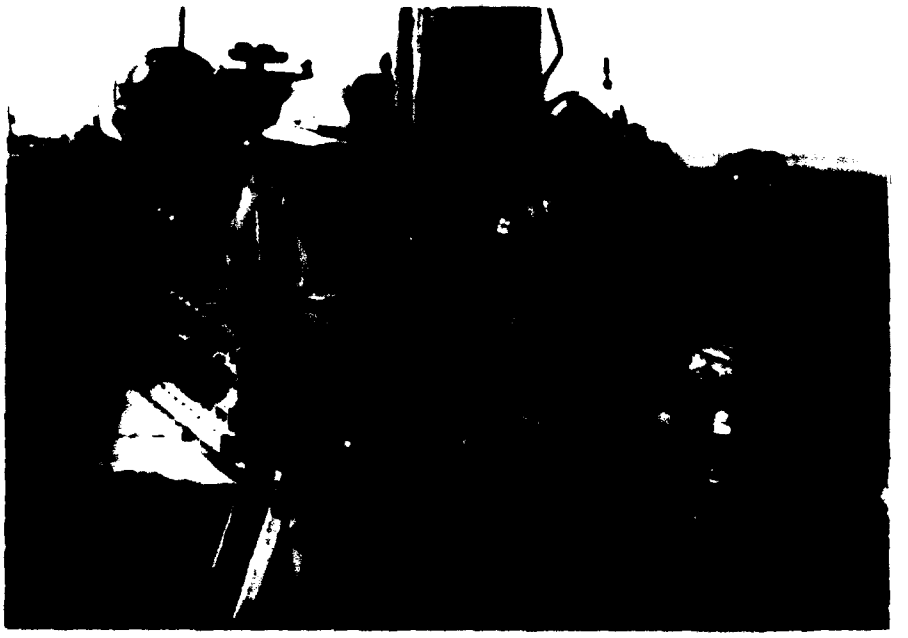


(Photo 4) 3-inch Diameter Downhole Air Hammer Drill

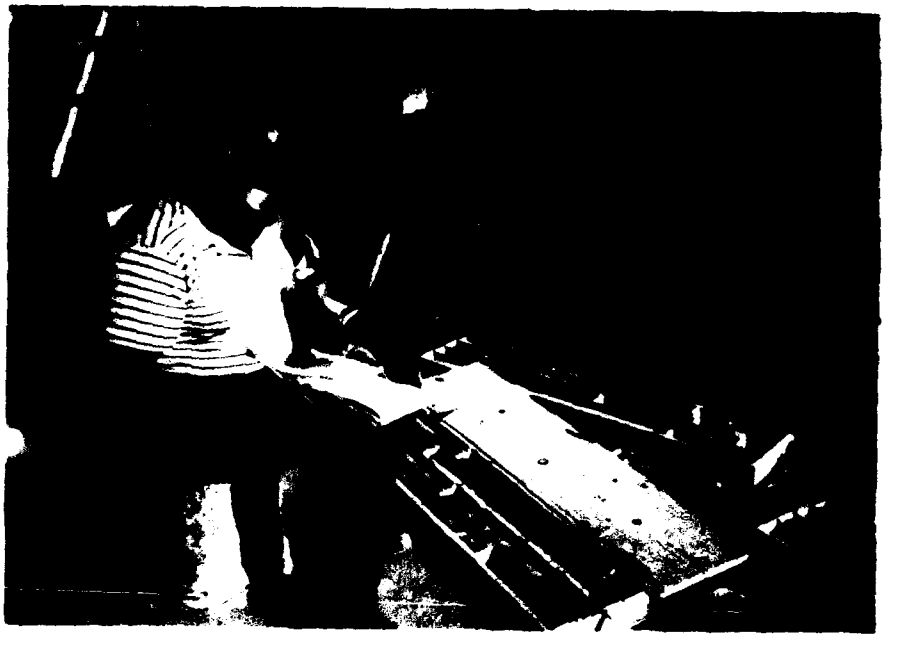


(Photo 5) Drilling in the lower zone of competent rock with air hammer

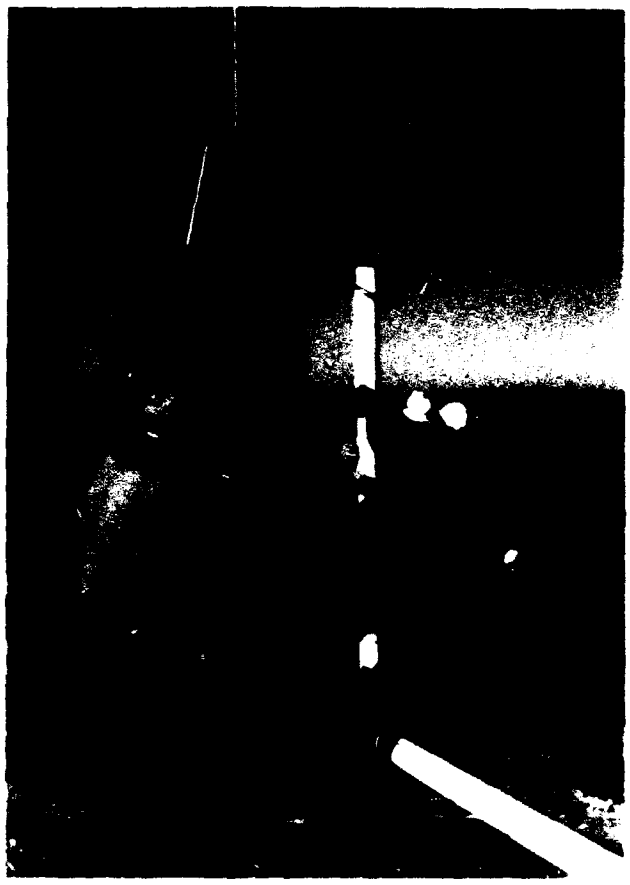
(Photo 6) NQ Rock Coring Bits



(Photo 7) Geologists discussing rock cores from NQ wire line barrel



(Photo 8) Geologist logging rock cores



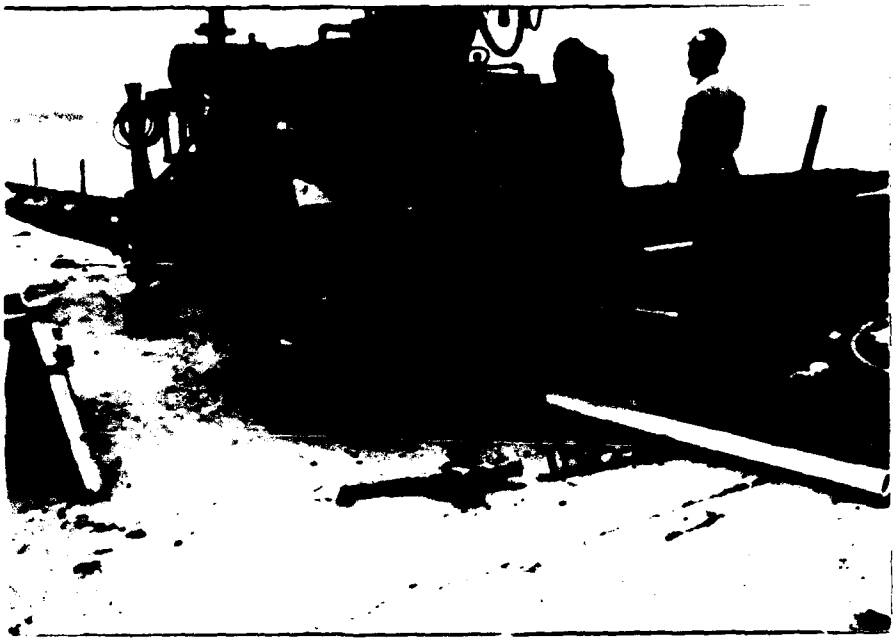
(Photo 9) Setting PVC casings for observation well

(Photo 10) Drilling through embankment casing with rotary rock bit

(Photo 11) Submersible air pump pumping drill water from the lake

(Photo 12) Washing out a hole prior to testing and grouting

(Photo 13) Pneumatic packer for water pressure testing



(Photo 14) Assembly of double ended packer

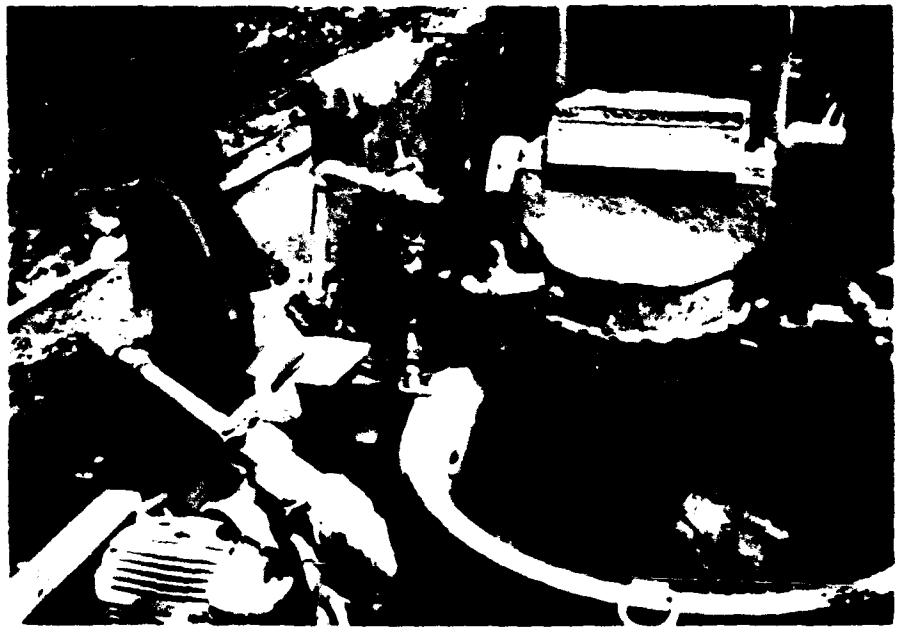
(Photo 15) Calculaton of flow in water pressure test

(Photo 16) Monitoring gages during a water pressure test

(Photo 17) Charging the main grout plant with bulk cement

(Photo 18) Loading the sand hopper on main plant

(Photo 19) Setting up a grout mix with the computerized batch plant

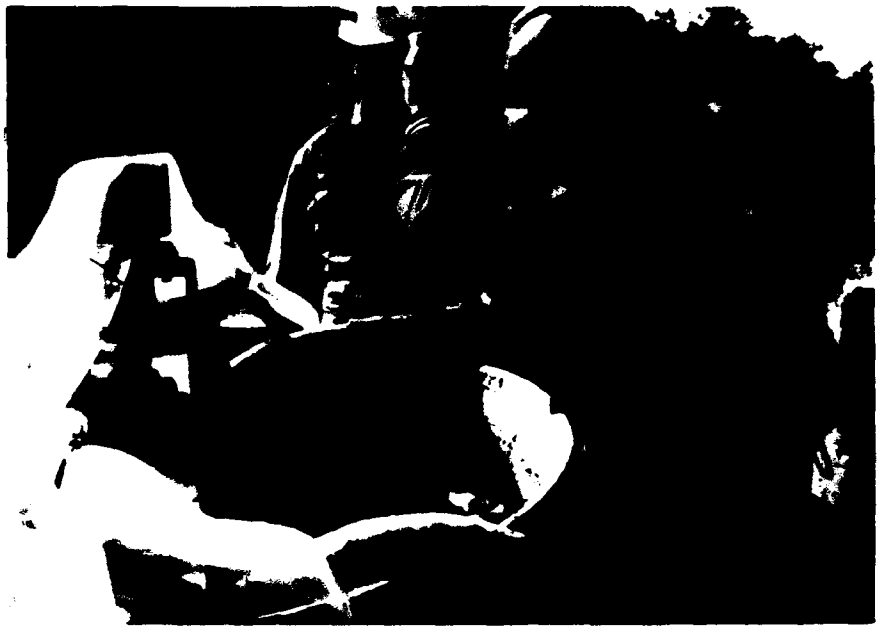


(Photo 20) Charging the main mixing tank

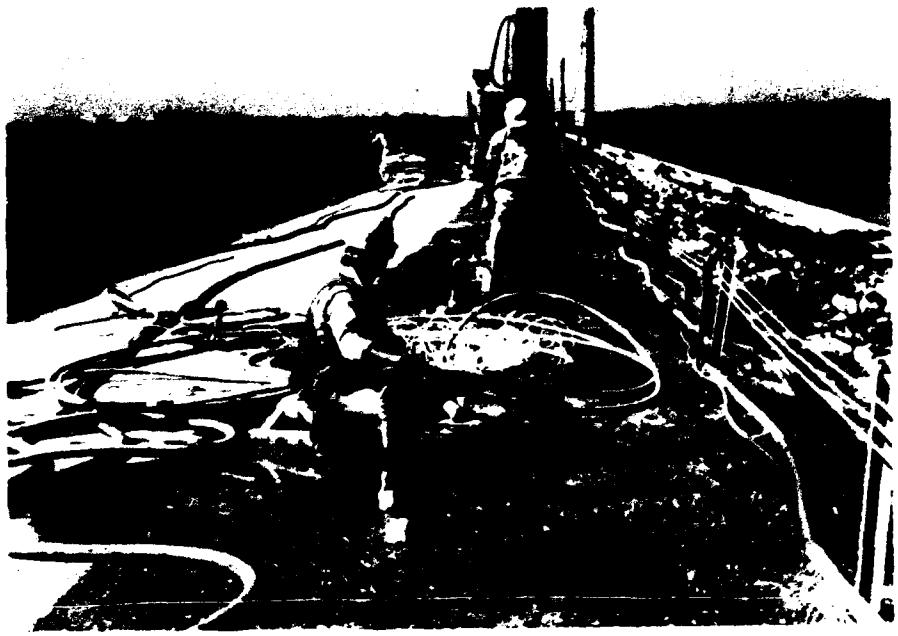
(Photo 21) Sending a mix from the main plant to a satellite mixer

(Photo 22) Measuring grout flow from satellite mixer as it is pumped into the foundation

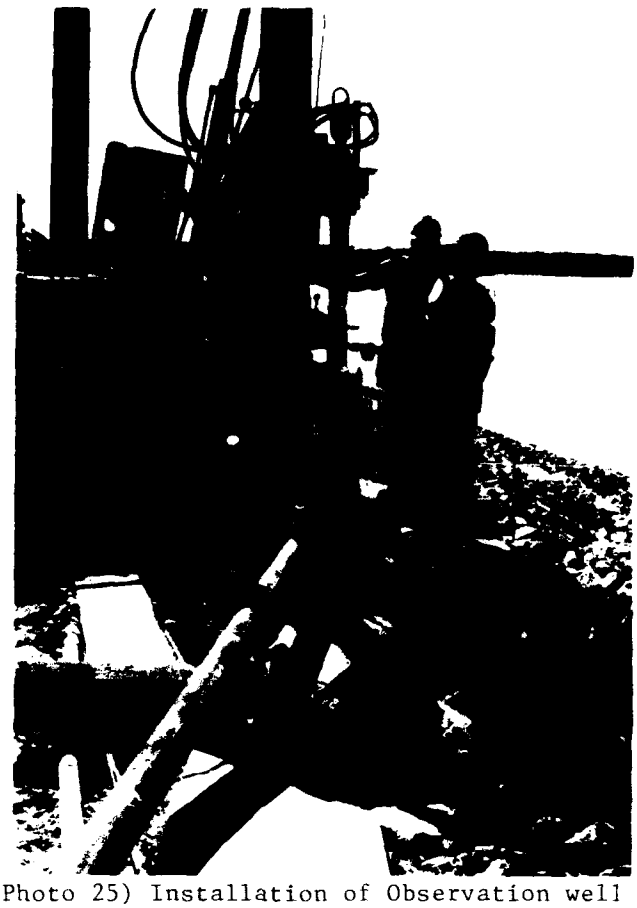
TOP ELEVATION 798.5



(Photo 23) Timing a batch of 2:1 grout flow



(Photo 24) Monitoring grout flow and setting pressures on hole TP-26X



(Photo 25) Installation of Observation well R-92-2a at Sta. 35+40, top of dam upstream side

(Photo 26) Installation of Observation Well R-92 at Sta. 35+40, top of dam downstream side

Appendix C

References

References

a. Red Rock Dam, Des Moines River, Iowa - Investigation of Underseepage, First Year of Operation - NCRED-F, 17 April 1970.

b. Effects of Red Rock Dam on Water Supply of Pella, Iowa, U.S. Geological Survey Administrative Report, July 1971.

c. Red Rock Dam, Des Moines River, Iowa - Investigation of Underseepage 1970-1974, NCRED-F, 16 September 1975.

d. Red Rock Dam, Des Moines River, Iowa - Investigation of Underseepage 1980-1984, NCRED-G, 4 June 1984.

e. Red Rock Dam, Des Moines River, Iowa - Investigation of Underseepage, NCRED-G (unpublished draft) 7 November 1986.

f. CENCR-ED memorandum, dated 20 May 1988, Subject: Red Rock Dam, Des Moines River, Iowa, "Reconnaissance Report for Dam Safety Assurance," with three endorsements.

g. Analysis of the Groundwater Flow System, Geochemistry, and Underseepage in the Vicinity of the Red Rock Dam near Pella, Iowa, U.S. Geological Survey, Water Resources Investigation Report 91-4092, 1991.

h. Red Rock Reservoir, Howell Dam Site, Des Moines River, IA; Design Memorandums 2, 6, 9, and 13.

i. Exploration and Piezometer Instrumentation for Red Rock Dam, Marion County IA prepared by Terracon, Inc., DACW25-87-D-0035, 23 September 1987 and Work Order No. 2, 21 July 1988.

j. Red Rock Dam Seepage Investigation History; CENCR-ED-G memorandum for ED, 21 December 1990.

k. Original contract plans and specifications for solicitation CIVENG-11-117-62-19, Construction of Dam - Stage II, Spillway and Concrete Overflow Sections, Red Rock Reservoir, Des Moines River, Marion County, Iowa.

l. Original contract plans and specifications for solicitation CIVENG-11-117-64-21, Foundation Treatment, Red Rock Reservoir, Des Moines River, Marion County, Iowa.

m. Original contract plans and specifications for solicitation CIVENG-11-117-66-37, Construction of Dam - Stage III, Red Rock Reservoir, Des Moines River, Iowa.

n. Red Rock Reservoir Dam Foundation Report, Binder 3 of 4.

o. Red Rock Reservoir Dam Foundation Report, Binder 4 of 4.

p. CENCR-ED-DM, Red Rock Dam, Des Moines River, Iowa, Seepage Study and Design Analysis Report, March 1991.

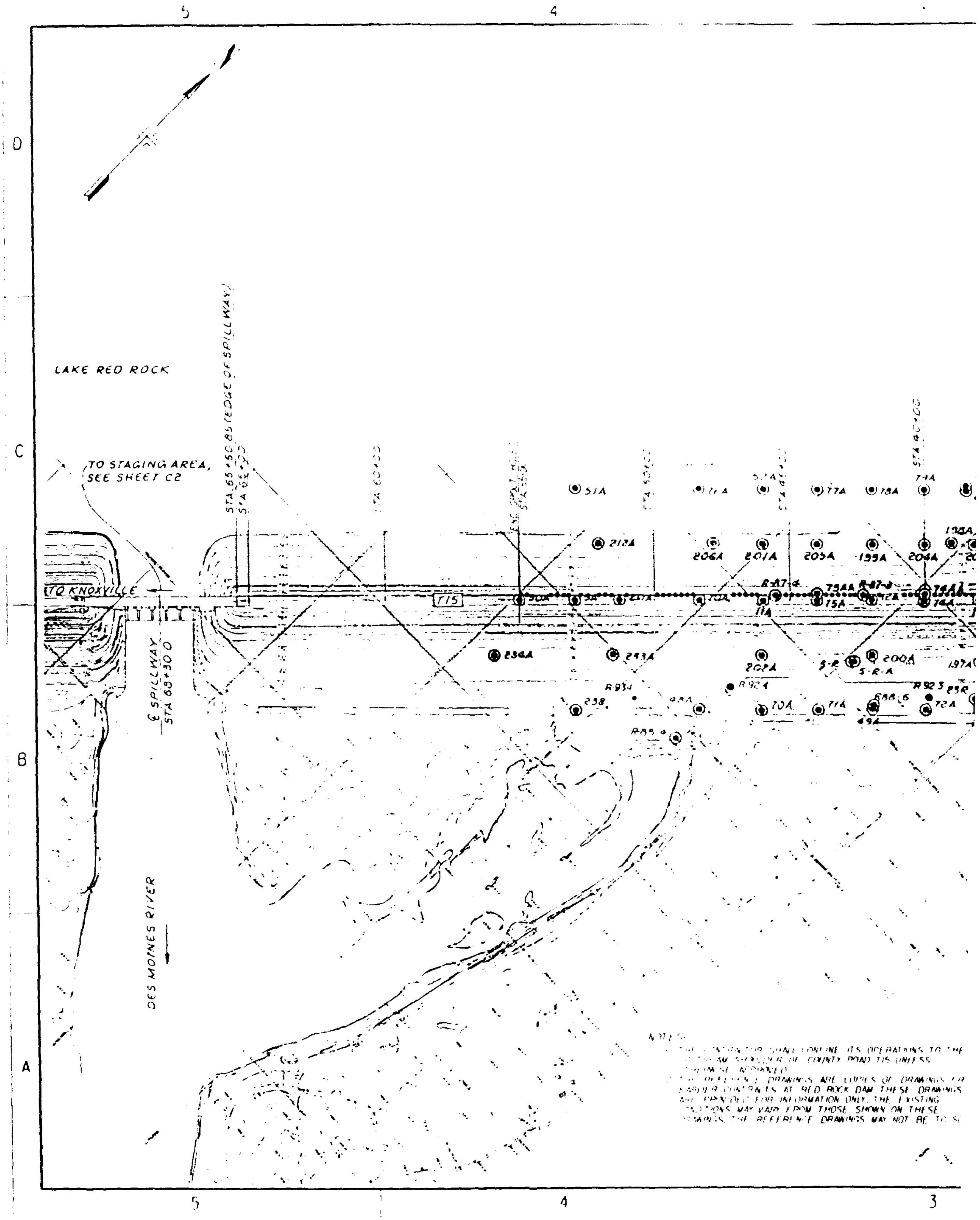
q. Red Rock Lake Project, Des Moines River, Iowa; Post Highwater Inspection Report, March 1992.

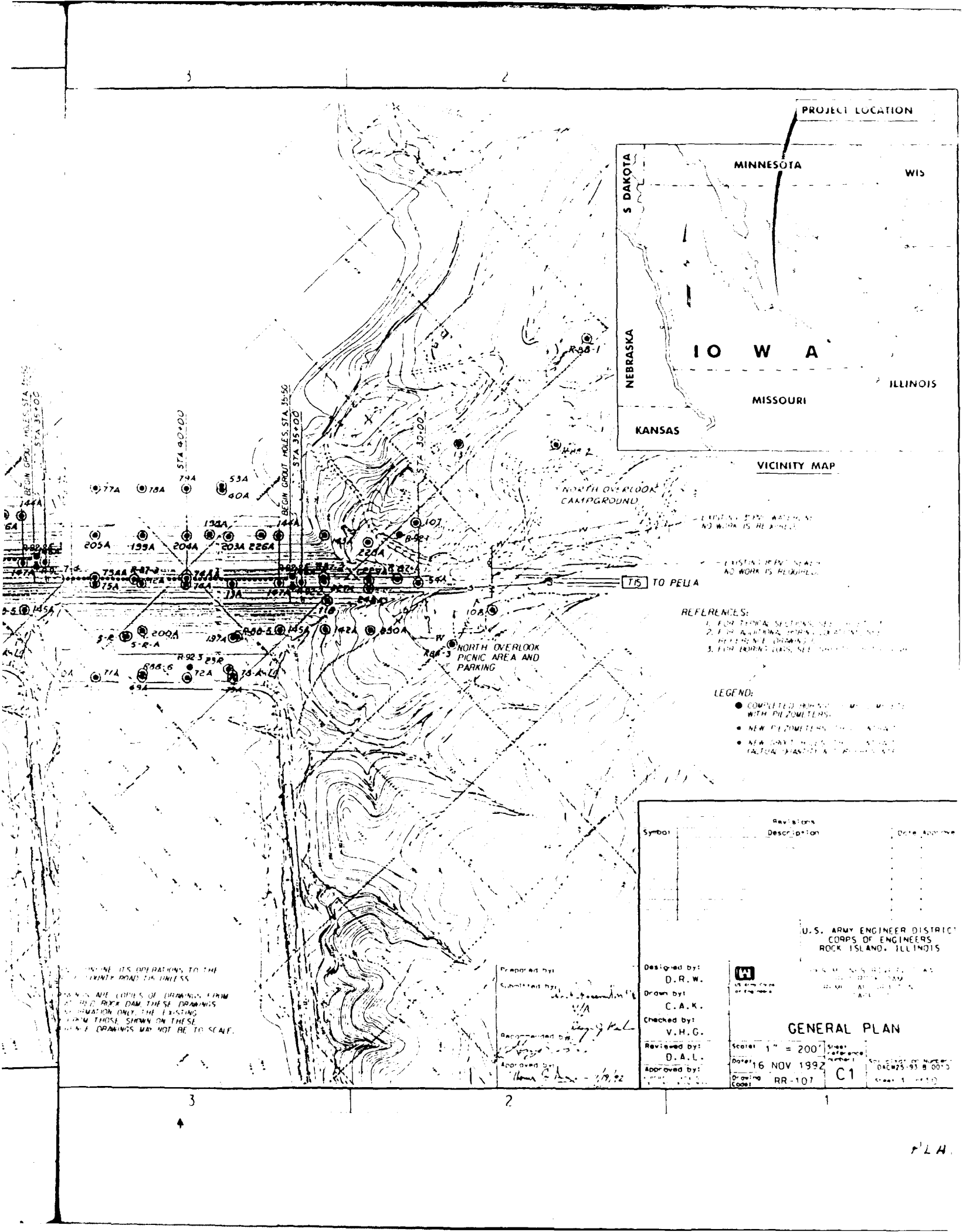
r. Red Rock Dam - Lake Red Rock; Periodic Inspection Report No. 10, Binders 1 and 2, May 1992.

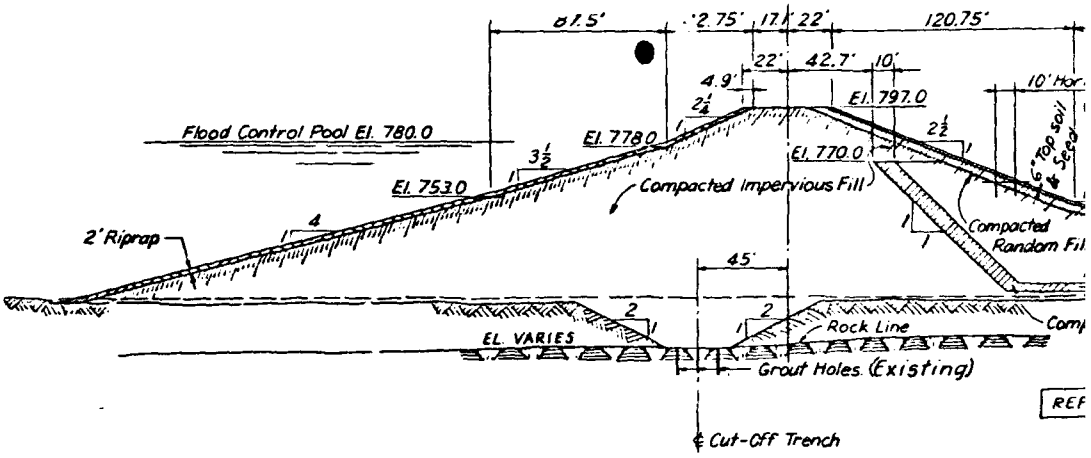
s. Observation Well and Piezometer Installations, Lake Red Rock, Marion County, Iowa. Prepared under DACW 25-91-C-0056 by The Judy Company, 20 October 1992.

Appendix D

Plates

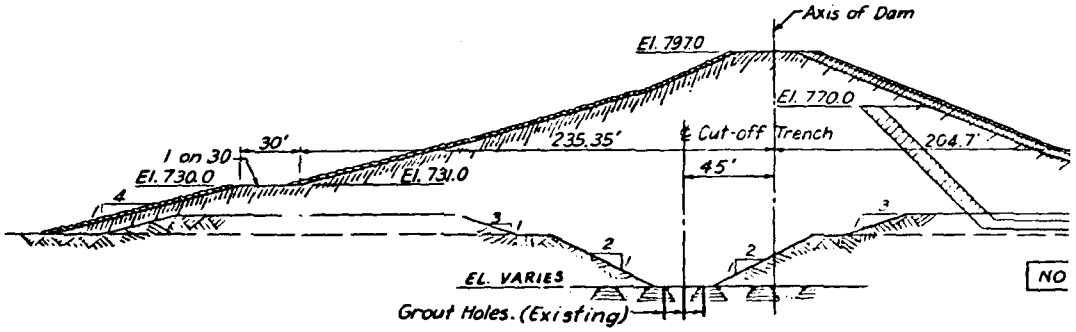

LAKE RED ROCK
TO STAGING AREA, SEE SHEET C2
TO KNOXVILLE
STA 65+50.85 (EDGE OF SPILLWAY)
℄ SPILLWAY STA 68+30.0
DES MOINES RIVER
STA 40+00
T15
51A
212A
206A
201A
205A
199A
204A
75A
234A
233A
202A
200A
5-R-A
238
70A
71A
72A
NOTES:
ITS OPERATIONS TO THE
OF COUNTY ROAD T15 UNLESS
DRAWINGS ARE COPIES OF DRAWINGS FOR
AT RED ROCK DAM. THESE DRAWINGS
FOR INFORMATION ONLY. THE EXISTING
MAY VARY FROM THOSE SHOWN ON THESE
REFERENCE DRAWINGS MAY NOT BE TO


PROJECT LOCATION
MINNESOTA
WIS
S DAKOTA
NEBRASKA
IOWA
ILLINOIS
MISSOURI
KANSAS
VICINITY MAP
STA 40+00
STA 35+00
STA 30+00
BEGIN GROUT HOLES, STA 35+50
NORTH OVERLOOK CAMPGROUND
NORTH OVERLOOK PICNIC AREA AND PARKING
TO PELLA
REFERENCES:
LEGEND:
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS
GENERAL PLAN
Designed by: D.R.W.
Drawn by: C.A.K.
Checked by: V.H.G.
Reviewed by: D.A.L.
Scale: 1" = 200'
Date: 16 NOV 1992
Drawing Code: RR-107
Sheet: C1



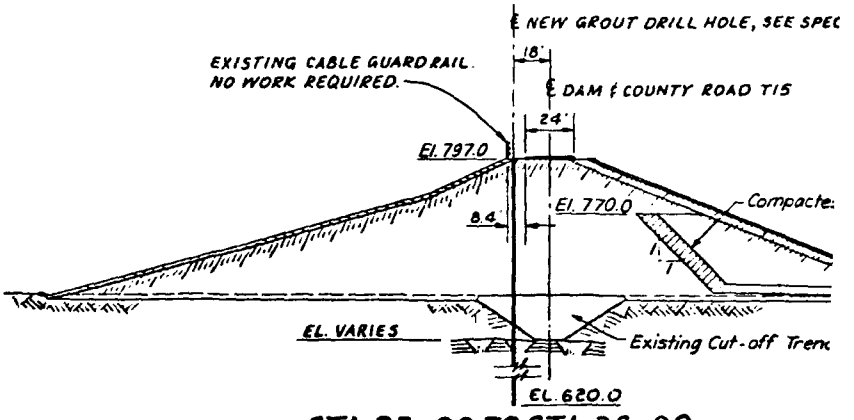
TYPICAL DAM SECTION

NOTE: LOOKING DOWN STATION



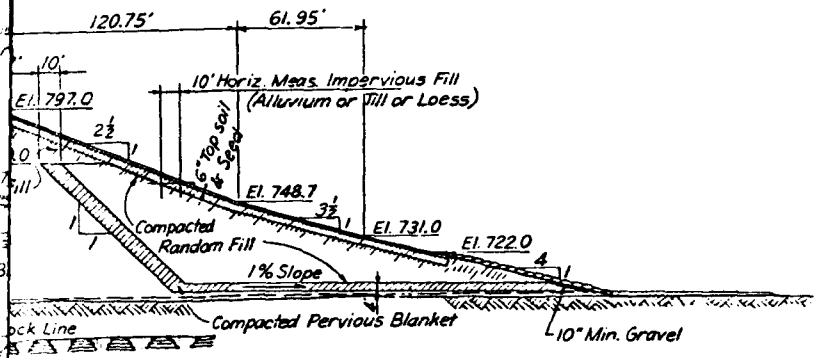
STA. 39+20 TO STA. 55+00

(STA. 39+20)
(LOOKING DOWN STATION)



STA. 25+00 TO STA. 36+00

(STA. 36+00)
(LOOKING DOWN STATION)

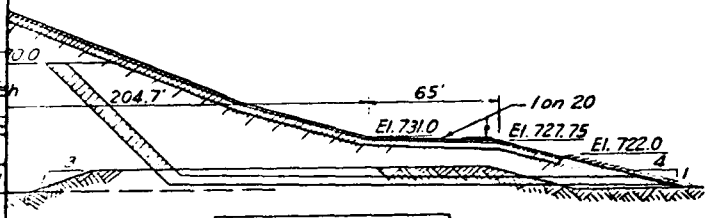


REFERENCE ONLY

ECTION

ATION

us of Dam



NO WORK REQUIRED

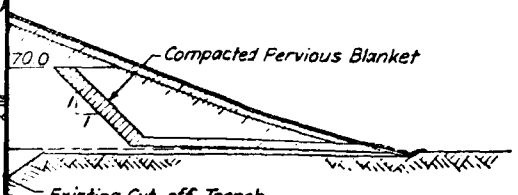
NOTE:
ELEVATIONS BASED ON SEA LEVEL DATUM OF 1929.

55+00

NOTE:
TRANSITION OF SECTIONS IS BETWEEN STA. 36+00 AND STA. 39+20.

OUT DRILL HOLE, SEE SPECS.

; COUNTY ROAD T15



36+00

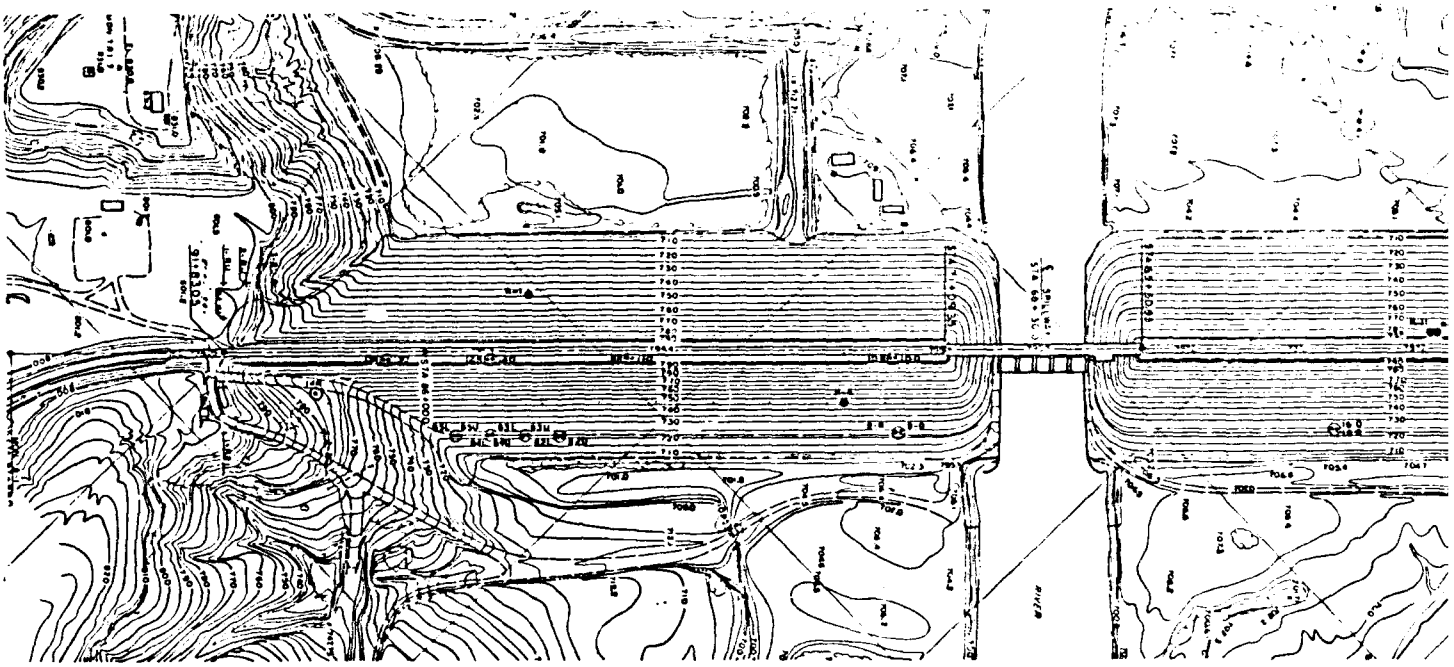
Symbol	Description	Date	Appro

0' 40' 80' 120'
SCALE

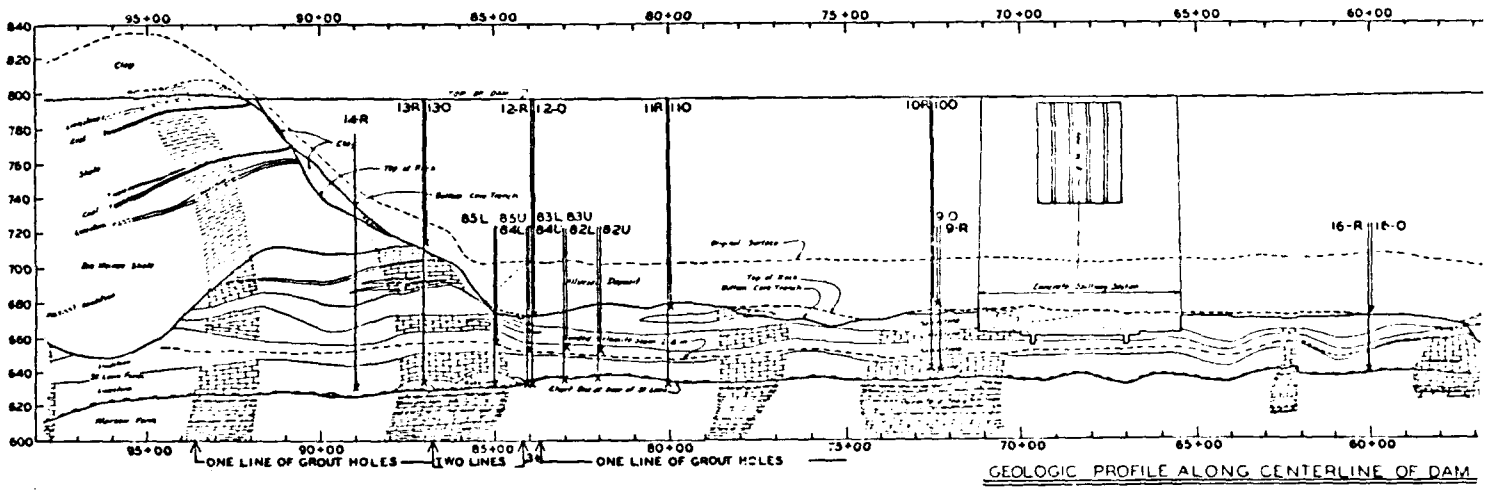
Revisions

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

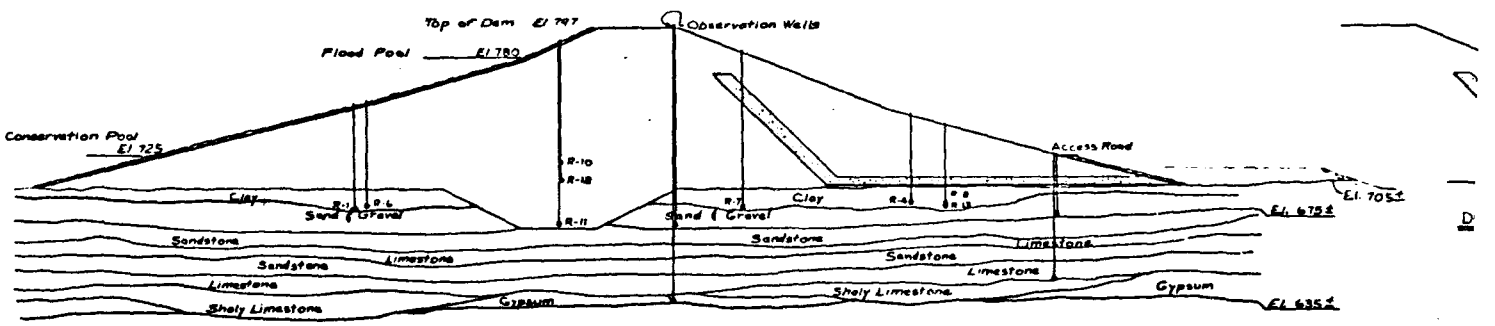
Designed by: D.R.W.	DES MOINES RIVER, IOWA RED ROCK DAM REMEDIAL GROUTING STAGE I		
Drawn by: R.L.G.			
Checked by: V.H.G.	TYPICAL SECTIONS		
Reviewed by: J.J.C.	Scale: 1"=40.0'	Sheet reference number: C3	SOLICITATION NO. DACW26-91-B-00
Approved by: JOHN R. BROWN COL., CORPS OF ENGINEERS	Date: 10 APRIL 1991 Drawing Code: RR-102		Sheet 3 of



PLAN

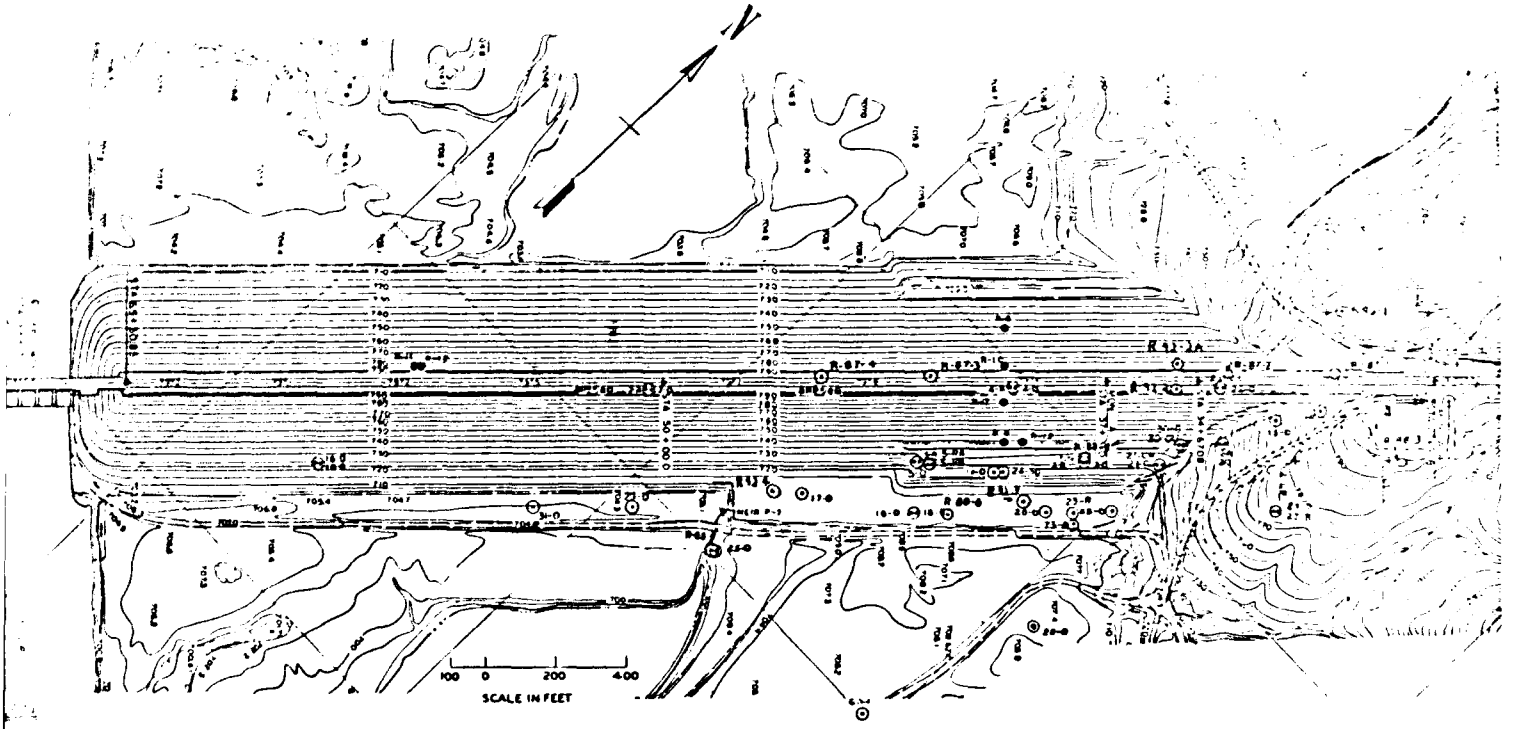


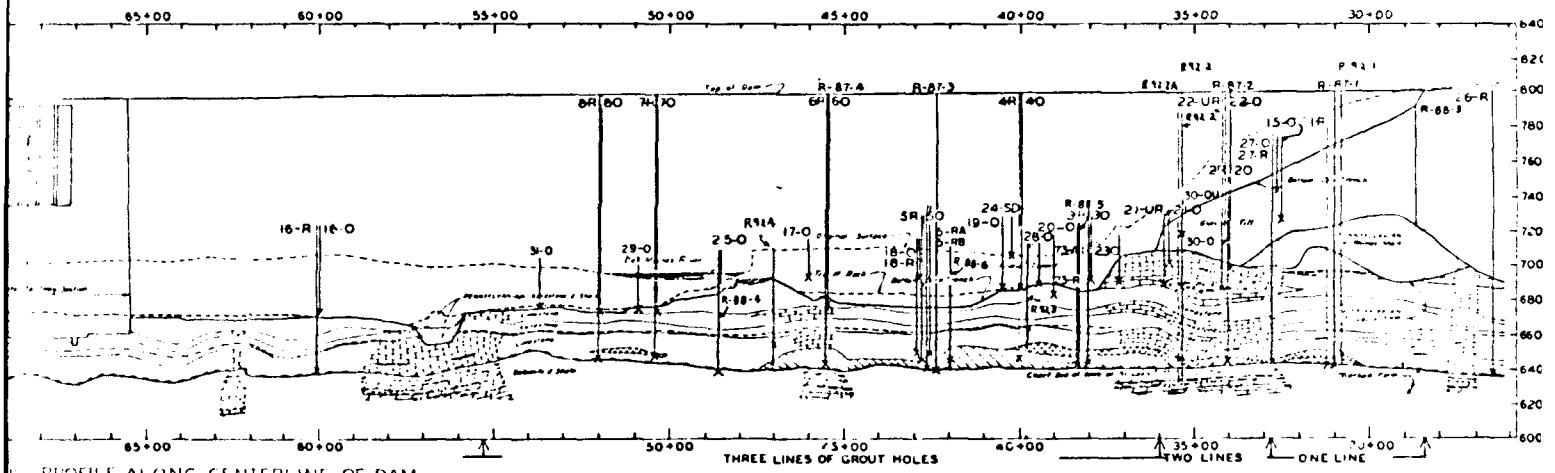
GEOLOGIC PROFILE ALONG CENTERLINE OF DAM



TYPICAL SECTION

10 0 20 40 60 80 100
SCALE IN FEET





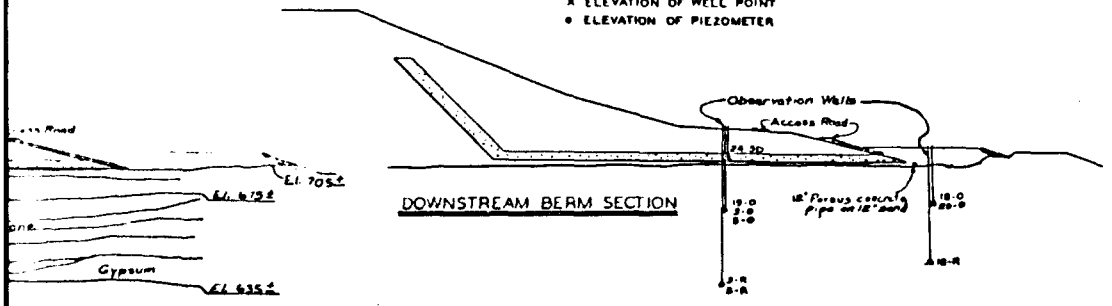
PROFILE ALONG CENTERLINE OF DAM

LEGEND.

- ● CONSTRUCTION PORE PRESSURE PIEZOMETERS (R-)
- ⊙ SEEPAGE OBSERVATION WELLS
  - -R ROCK GYPSIFEROUS ZONE
  - -L LOWER ROCK GYPSIFEROUS ZONE
  - -U UPPER ROCK SANDSTONE
  - -O OVERBURDEN ALSO GW-1
  - -UR UPPER ROCK LIMESTONE
  - -SD SAND DRAIN
- x ELEVATION OF WELL POINT
- • ELEVATION OF PIEZOMETER

NOTES

1. ROCK PROFILE VARIES DOWNSTREAM FROM CENTERLINE. SEE DETAIL LOG OF INSTALLATION FOR 2-O, 21-O, 23-O, 20-O, 6-O, 25-O, 7-O AND 11-O ROCK AND OVERBURDEN PROFILE OF DOWNSTREAM LEFT BANK AND ABUTMENT SHOWN SEPARATELY.
2. CONSTRUCTION GROUTING DATA SHOWN IN FOUNDATION REPORTS, BINDERS 1 THROUGH 4.



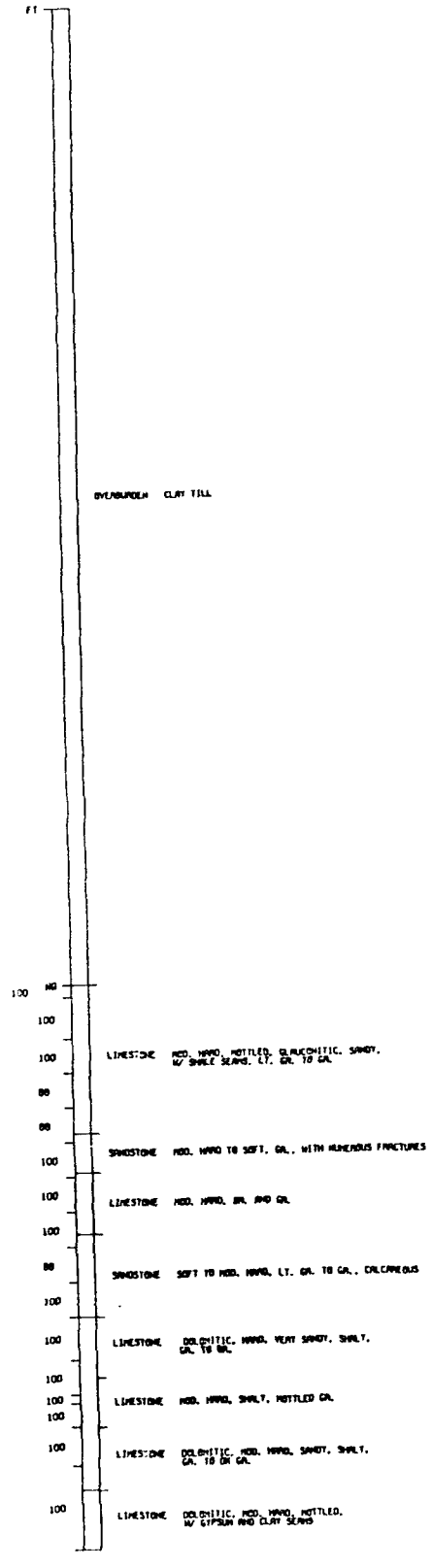
RED ROCK DAM

DES MOINES RIVER, IOWA

OBSERVATION WELLS AND GEOLOGIC PROFILE

S-22-X

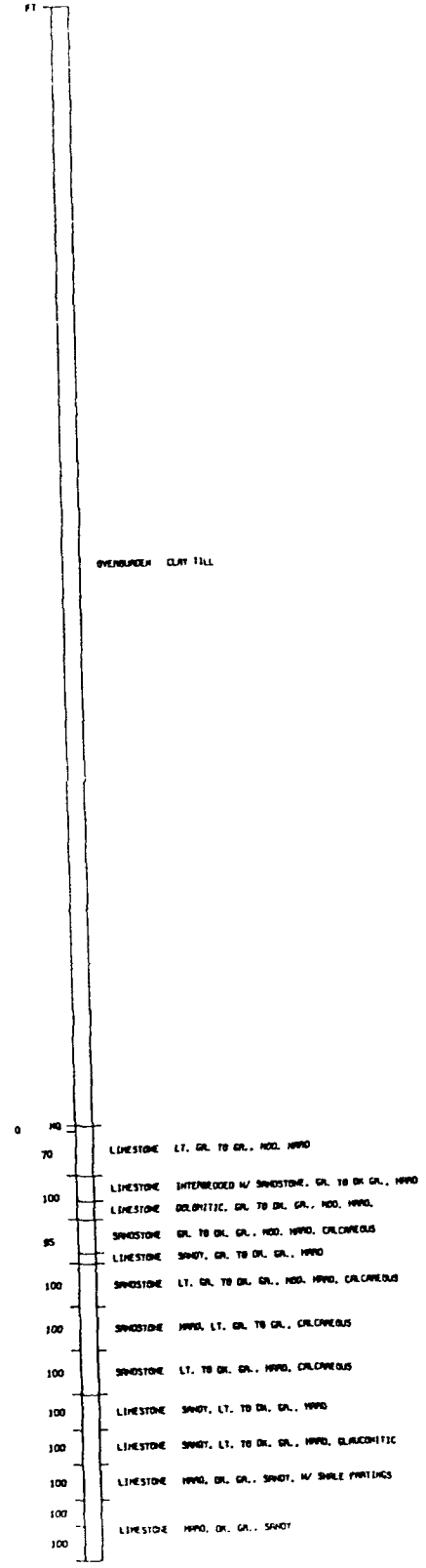
TOP ELEVATION 798.0



STA 29+30
15' UPSTREAM
8 OCTOBER 1991

P-17-X

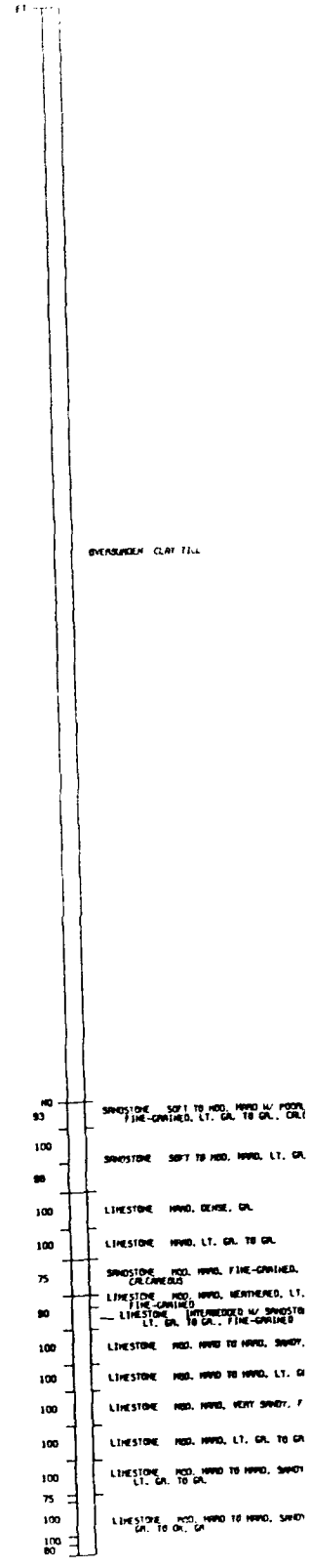
TOP ELEVATION 798.0



STA 28+20
15' UPSTREAM
9 OCTOBER 1991

S-3-X

TOP ELEVATION [illegible]



STA 25+50
15' UPSTREAM
15 OCTOBER 1991

ELEVATION 798.0

WEATHERED CLAY TILL

7 ZONES

DOLOSTONE SOFT TO MOD. HARD W/ POORLY CEMENTED ZONES FINE-GRAINED, LT. GR. TO GR., CALCAREOUS

CALCAREOUS

DOLOSTONE SOFT TO MOD. HARD, LT. GR. TO GR., CALCAREOUS

LIMESTONE HARD, DENSE, GR.

GR.,

LIMESTONE HARD, LT. GR. TO GR.

SANDY, SHALY.

DOLOSTONE MOD. HARD, FINE-GRAINED, LT. GR. TO GR., CALCAREOUS

LIMESTONE MOD. HARD, WEATHERED, LT. GR. TO GR., FINE-GRAINED

LIMESTONE DATE/BEDDED W/ SANDSTONE, SOFT, SANDY, SHALY, LT. GR. TO GR., FINE-GRAINED

LIMESTONE MOD. HARD TO HARD, SANDY, SHALY

LIMESTONE MOD. HARD TO HARD, LT. GR. TO GR.

LIMESTONE MOD. HARD, VERY SANDY, FINE-GRAINED.

LITE

LIMESTONE MOD. HARD, LT. GR. TO GR.

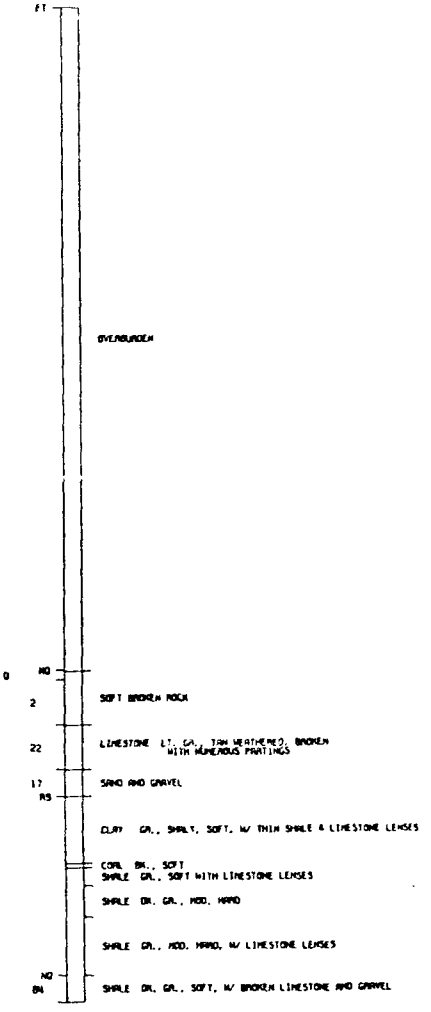
LIMESTONE MOD. HARD TO HARD, SANDY W/ GLAUCONITE LT. GR. TO GR.

LIMESTONE MOD. HARD TO HARD, SANDY, SHALY, LT. TO DK. GR.

91

P-1-X

TOP ELEVATION 798.5



STA 25+00
15' UPSTREAM
15 OCTOBER 1991

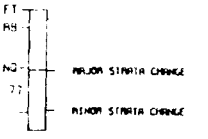
LEGEND

BORING NUMBER

HOLE ADVANCED BY FISHTAIL BIT
HOLE ADVANCED BY ROLLER BIT

STARTED CORING WITH SIZE INDICATED

PERCENT RECOVERY OF CORE FOR RUN INDICATED



LOCATION OF BORING
JULY 4, 1976 APPROXIMATE DATE OF DRILL

Revisions			
Symbol	Description	Date	Approv

U.S. ARMY ENGINEER DISTRIC
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

Designed by:
Drawn by:
Checked by:
Reviewed by:
Approved by:

US Army Corps of Engineers Rock Island District

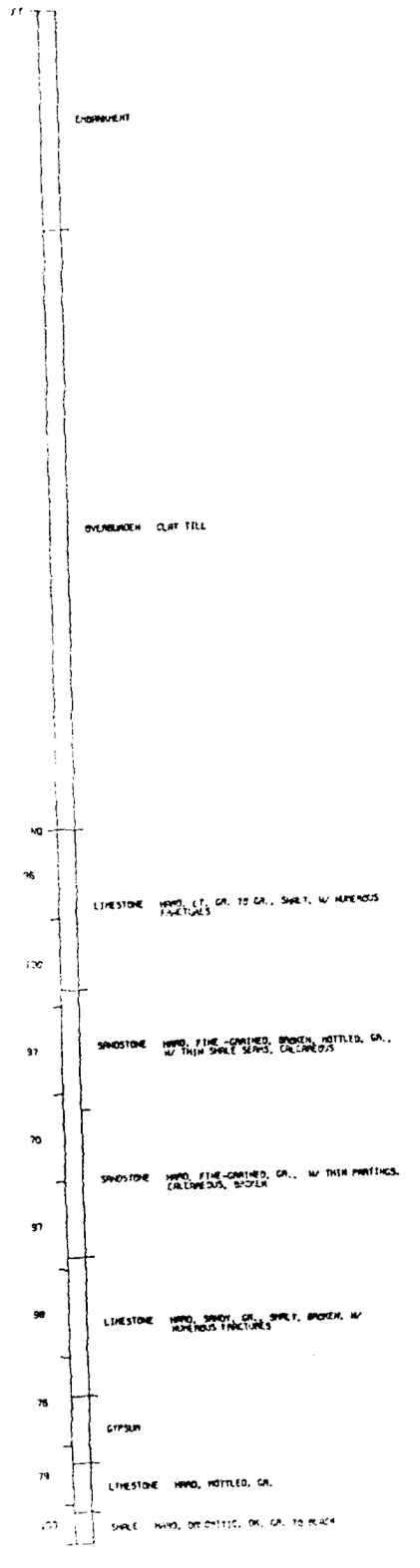
DES MOINES RIVER, IOWA
RED ROCK DAM
REMEDIAL GROUTING
STAGE I
Logs of Exploratory Cores
Sta. 25+00 - 29+30

Scale: 1" = 10'
Date:
Drawing Code:
Sheet reference number:
Solicitation Number:
Sheet | of

PLATE

P-28-BX

TOP ELEVATION 798.0

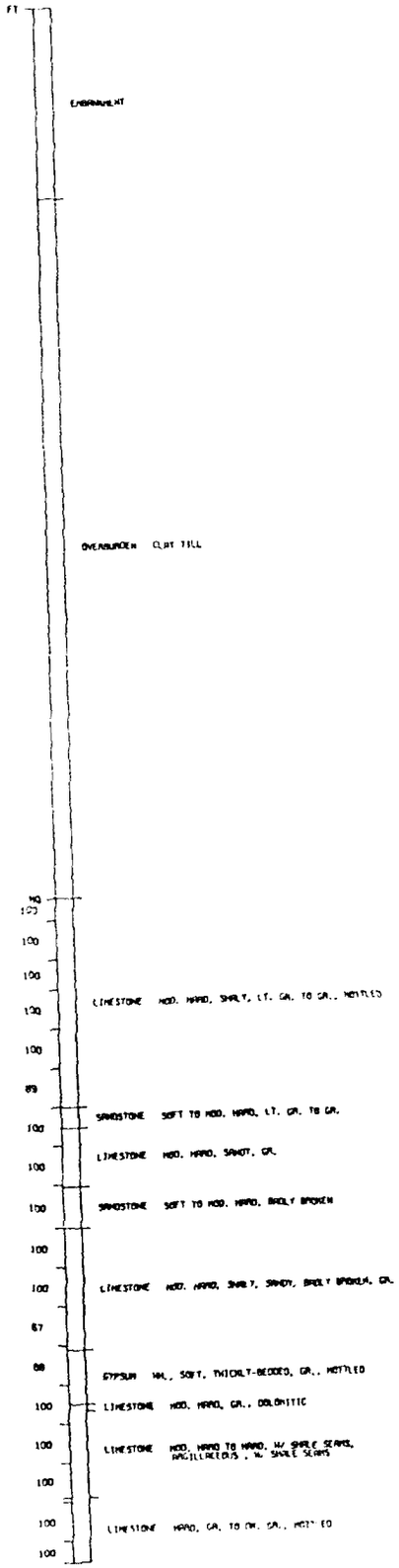


STA 30+47.5

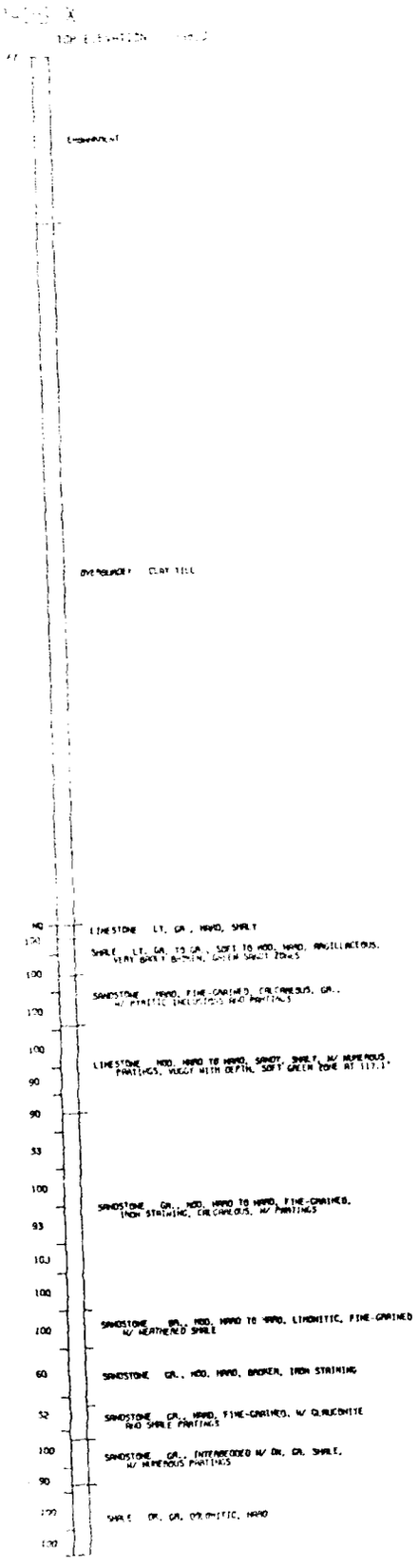
27 AUGUST 1992

P-27-X

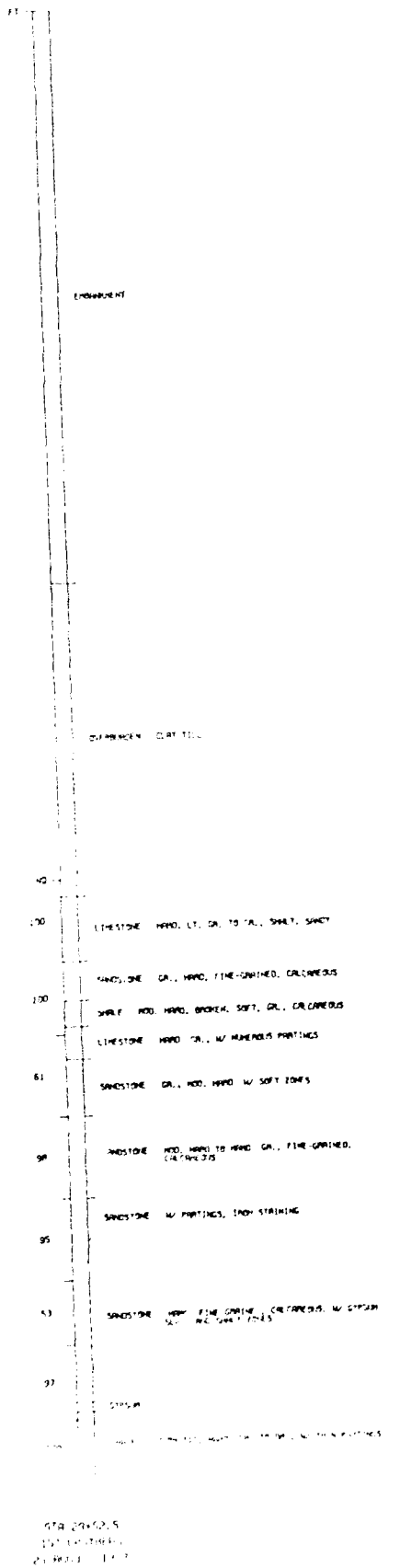
TOP ELEVATION 798.0

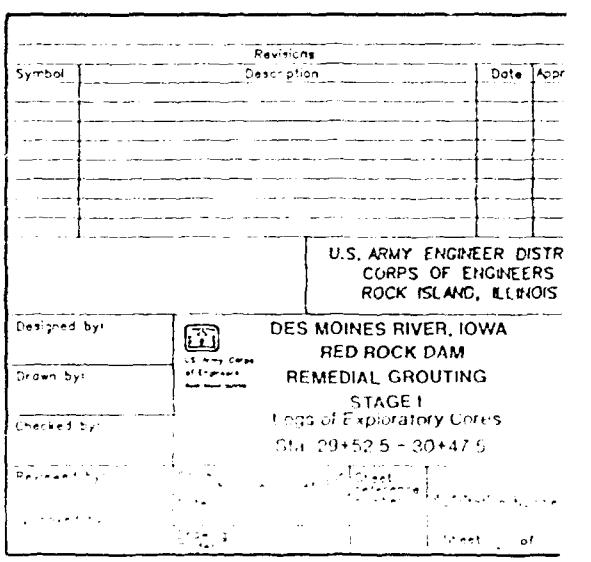


STA 30+20
15' UPSTREAM
24 OCTOBER 1991



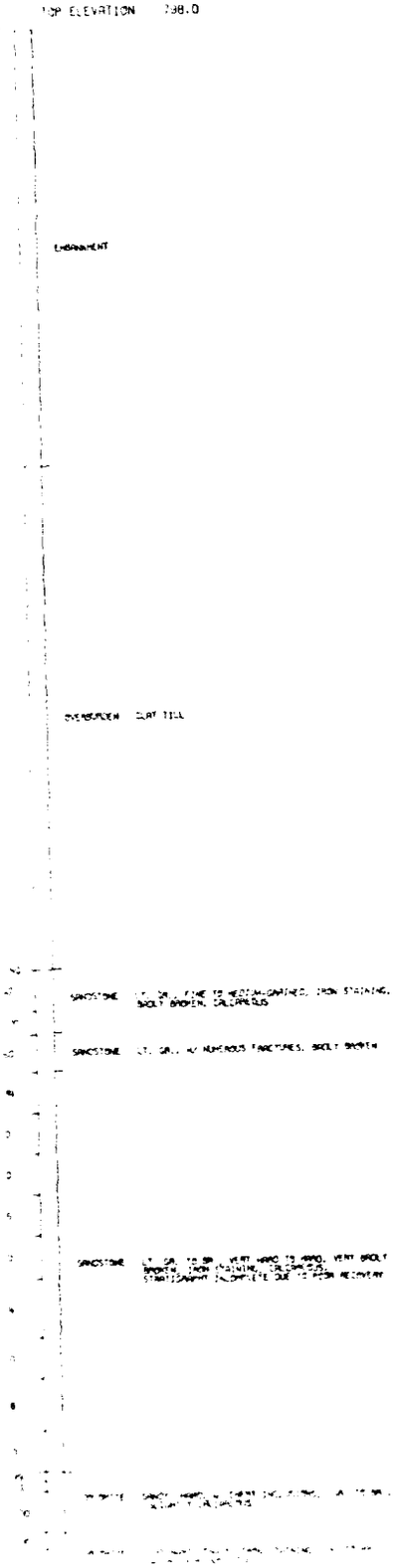
STA 29+85
15' UPSTREAM
11 MAY 1992


TOP ELEVATION
ENGINEER
LIMESTONE HARD, LT. GR. TO GR., SHALT, SANDY
SANDSTONE GR., HARD, FINE-GRAINED, CALCAREOUS
SHALE MOD. HARD, BROKEN, SOFT, GR., CALCAREOUS
LIMESTONE HARD GR., W/ NUMEROUS PARTINGS
SANDSTONE GR., MOD. HARD W/ SOFT ZONES
SANDSTONE W/ PARTINGS, IRON STAINING
SANDSTONE FINE GRAINED, CALCAREOUS, W/ STYLOL
STA 29+52.5


Revisions
Symbol
Description
Date
U.S. ARMY ENGINEER DISTR
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS
Designed by:
Drawn by:
Checked by:
DES MOINES RIVER, IOWA
RED ROCK DAM
REMEDIAL GROUTING
STAGE I
Logs of Exploratory Cores
STA 29+52.5 - 30+47.5

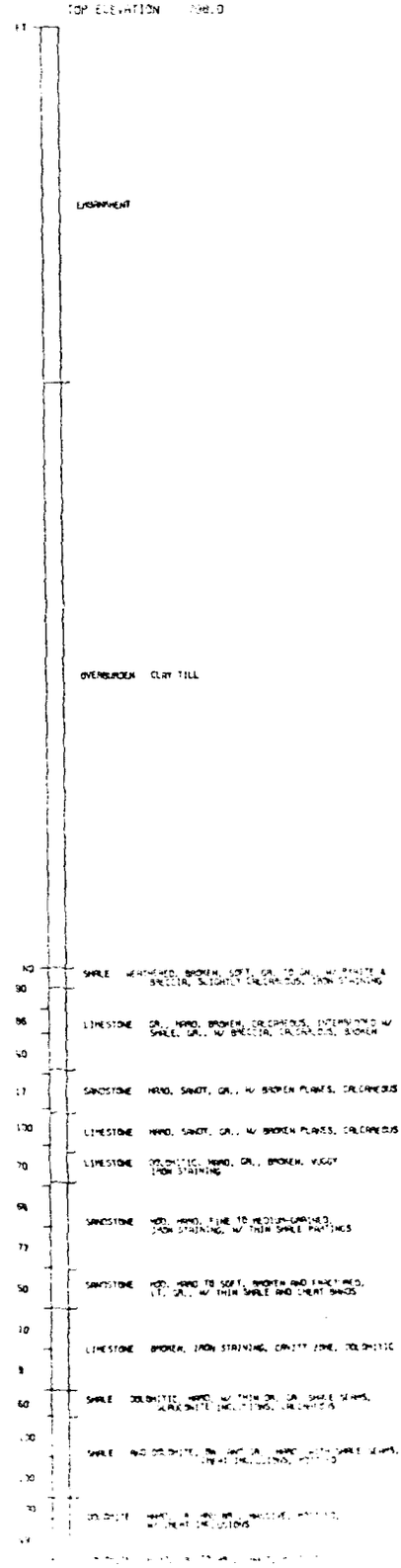
P-37-X

TOP ELEVATION 798.0



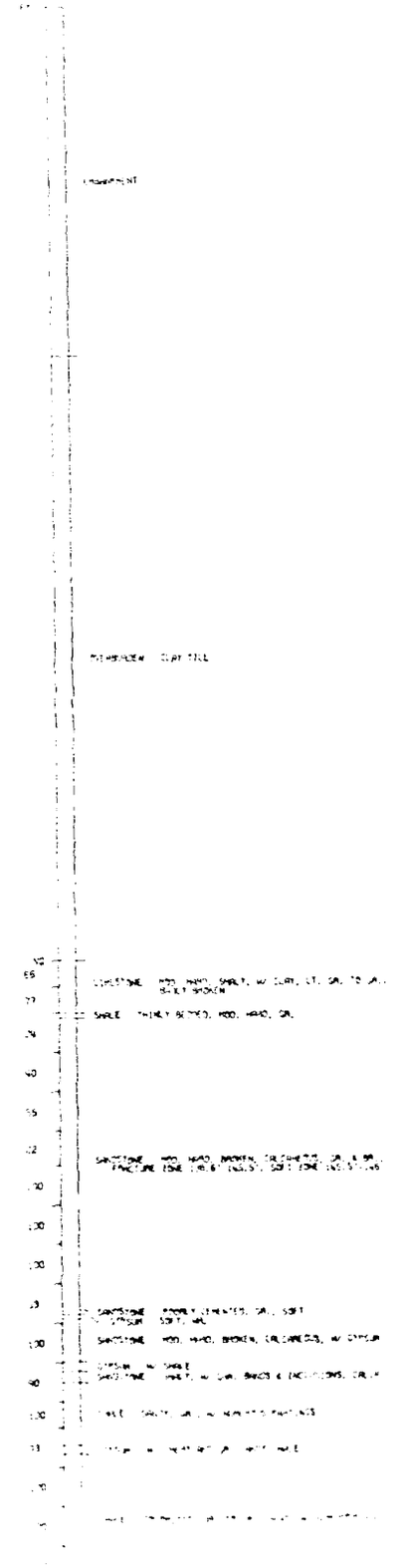
P-37-X

TOP ELEVATION 798.0



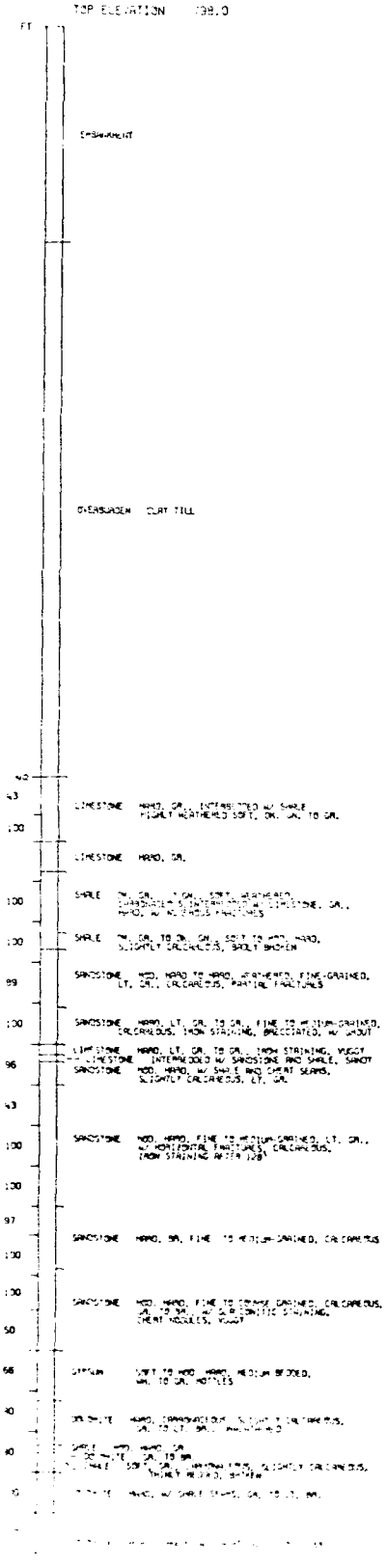
P-37-X

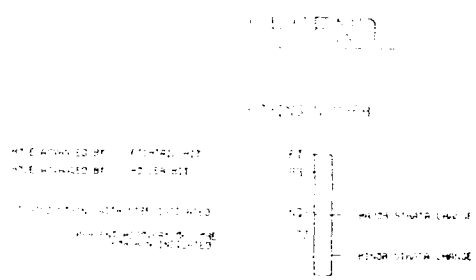
TOP ELEVATION 798.0



P-32-X

TOP ELEVATION 598.0





DATE OF BEGINNING
JULY 9, 1936 APPROXIMATE DATE OF

Revisions			
Description	Date	Appr

U.S. ARMY ENGINEER DISTR
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

Designed by:
Drawn by:
Checked by:
Submitted by:

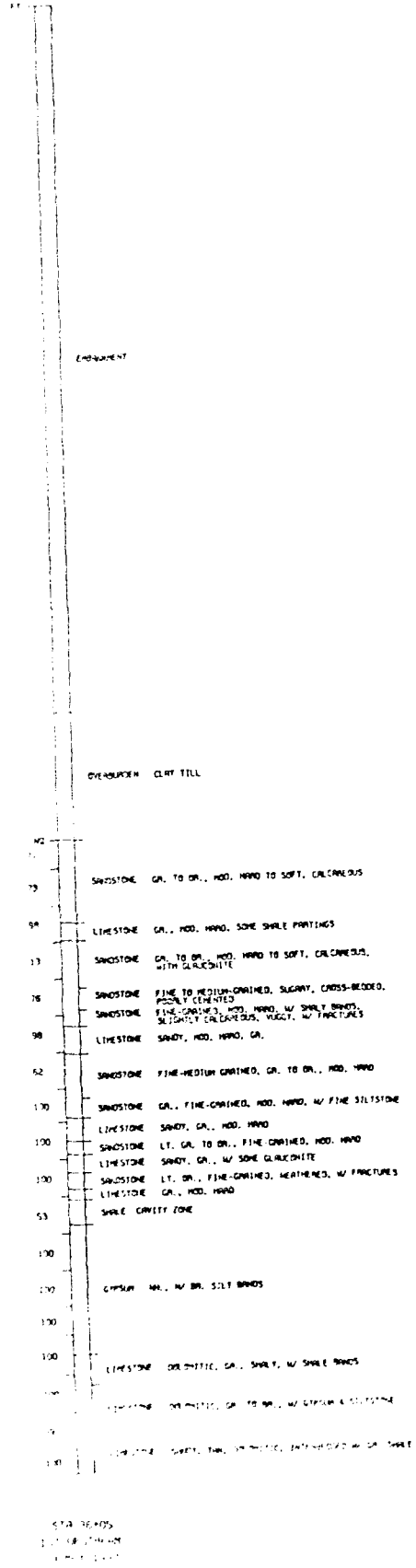
DES MOINES RIVER, IOWA
RED ROCK DAM
REMEDIAL GROUTING
STAGE I
Logs of Exploratory Cores
Sta 31+20 - 33+20

Date
Sheet reference number
Sheet of

PLA

S-55-X

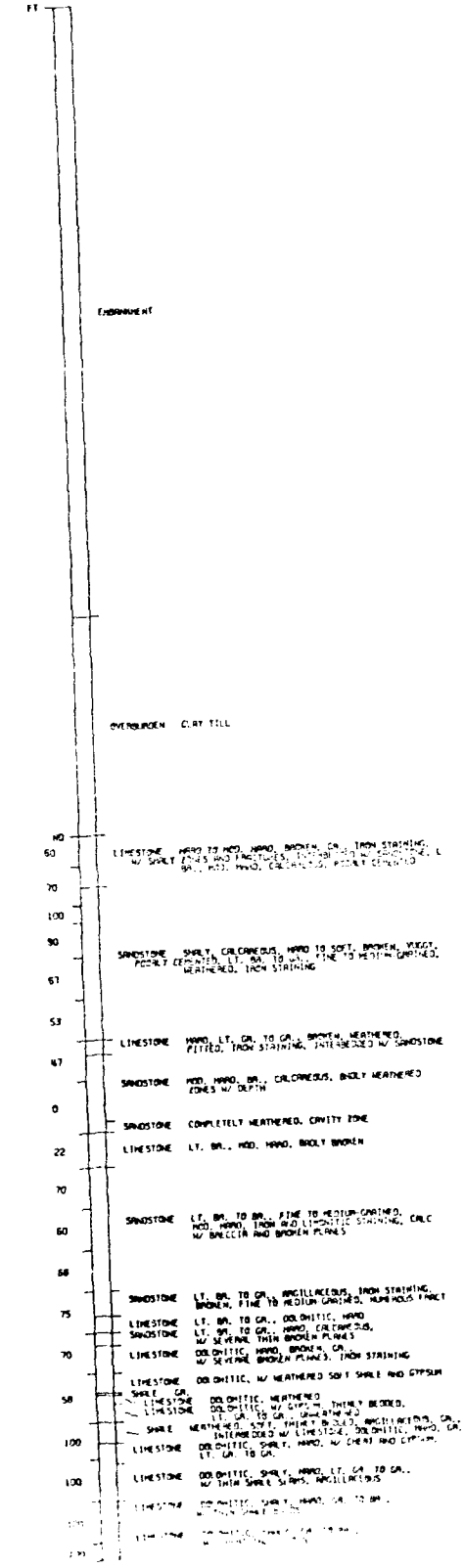
TOP ELEVATION 798.0



STA 36+05

S-53-X

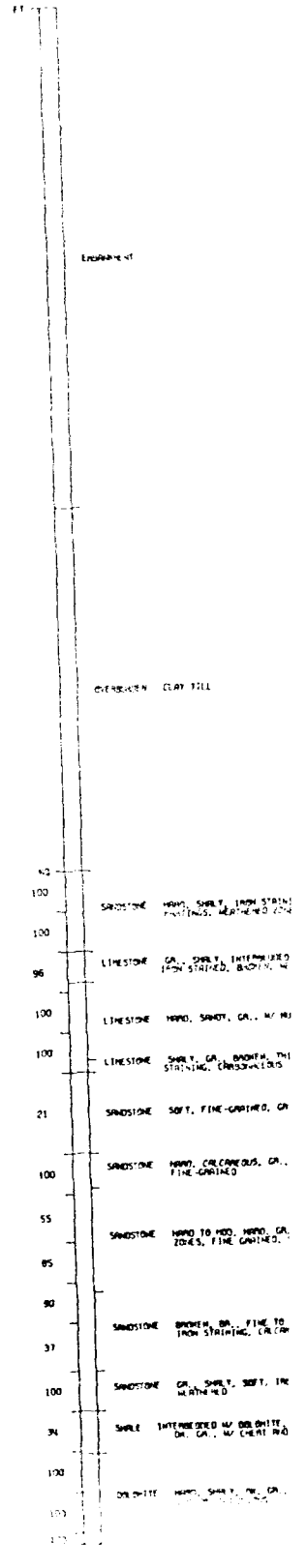
TOP ELEVATION 798.0



STA 35+50
15' UPSTREAM
7 APRIL 1982

P-47-X

TOP ELEVATION 798.0



STA 34+20
15' UPSTREAM
17 APRIL 1982

P-43-X

TOP ELEVATION 798.0

EMBANKMENT

OVERBURDEN CLAY TILL

100 NO LIMESTONE SANDY, VERY HARD, GR., SLICKENSIDED
SHALE DK. GR., INTERBEDDED W/ LIMESTONE, HARD, SANDY, BADLY BROKEN, WEATHERED

93

62 SANDSTONE MOD. HARD, W/ NUMEROUS FRACTURES, BROKEN, SHALY, GR., FINE TO MEDIUM-GRAINED, IRON STAINING

92

100 SANDSTONE VERY HARD, W/ NUMEROUS PARTINGS, CALCAREOUS

SANDSTONE HARD, FINE TO MEDIUM-GRAINED, W/ SHALE PARTINGS, IRON AND LIMONITIC STAINING

100

SANDSTONE MOD. HARD, BR., W/ THIN SHALE PARTINGS, IRON STAINING, BROKEN

58

28

100

SANDSTONE MOD. HARD TO HARD, GR. TO BROWN W/ NUMEROUS SHALE PARTINGS, IRON STAINING, BROKEN

100

38 DOLOMITE SHALY, VERY HARD, PITTED, IRON STAINING

100

SHALE

100

DOLOMITE HARD, SHALY, PITTED, IRON STAINING

STA 33+40
15' UPSTREAM
15 APRIL 1932

LEGEND

BORING NUMBER

HOLE ADVANCED BY FISHTAIL BIT
HOLE ADVANCED BY ROLLER BIT

STARTED DRILLING WITH SIZE INDICATED

PERCENT RECOVERY OF CORE FOR RUN INDICATED

FT
A3
NO — MAJOR STRATA CHANGE
77
MINOR STRATA CHANGE

LOCATION OF BORING
JULY 4, 1976 APPROXIMATE DATE OF

Revisions			
Symbol	Description	Date	Ap

U.S. ARMY ENGINEER DIS
CORPS OF ENGINEER
ROCK ISLAND, ILLINO

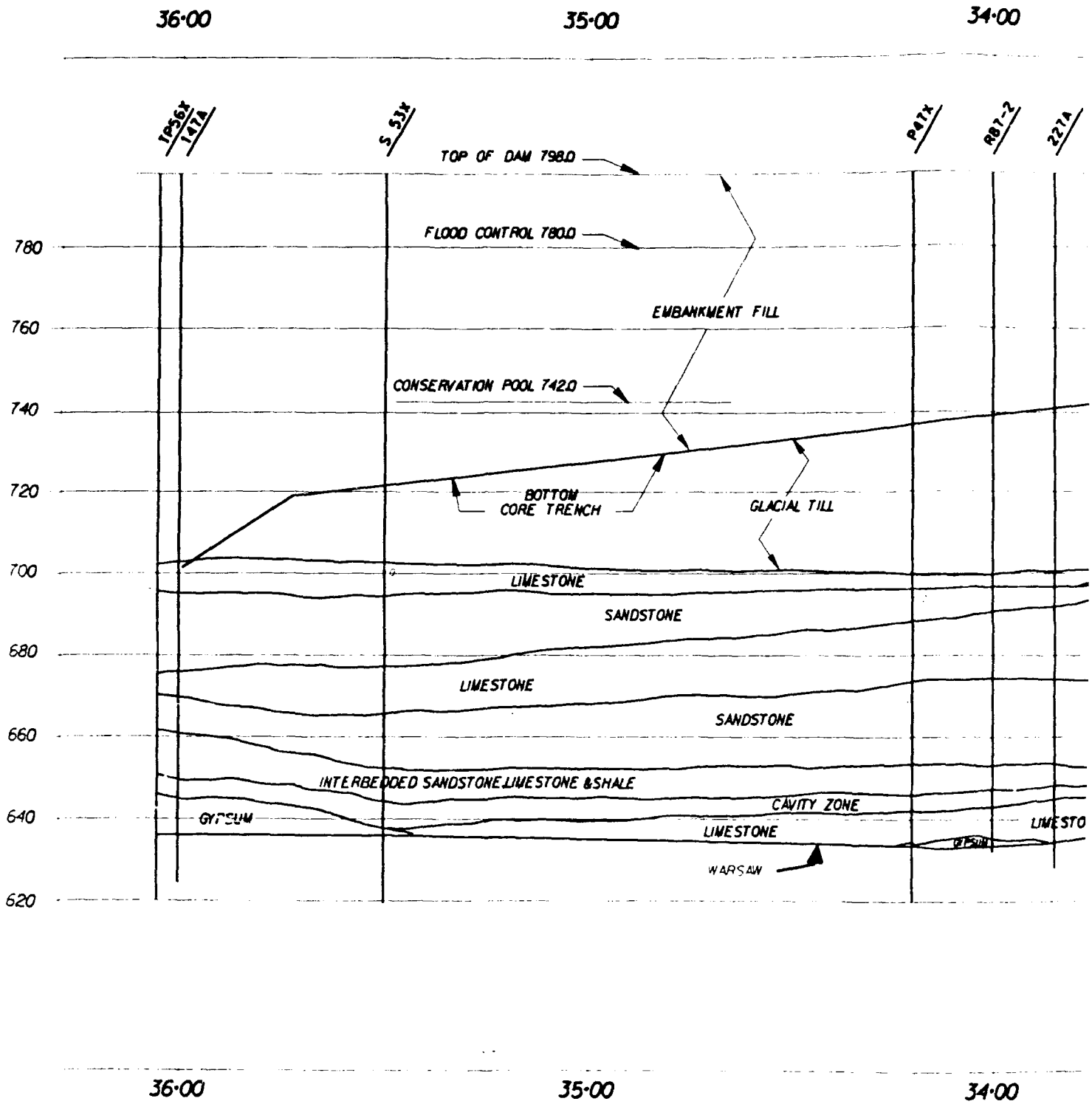
Designed by:
Drawn by:
Checked by:
Reviewed by:
Approved by:

U.S. Army Corps of Engineers

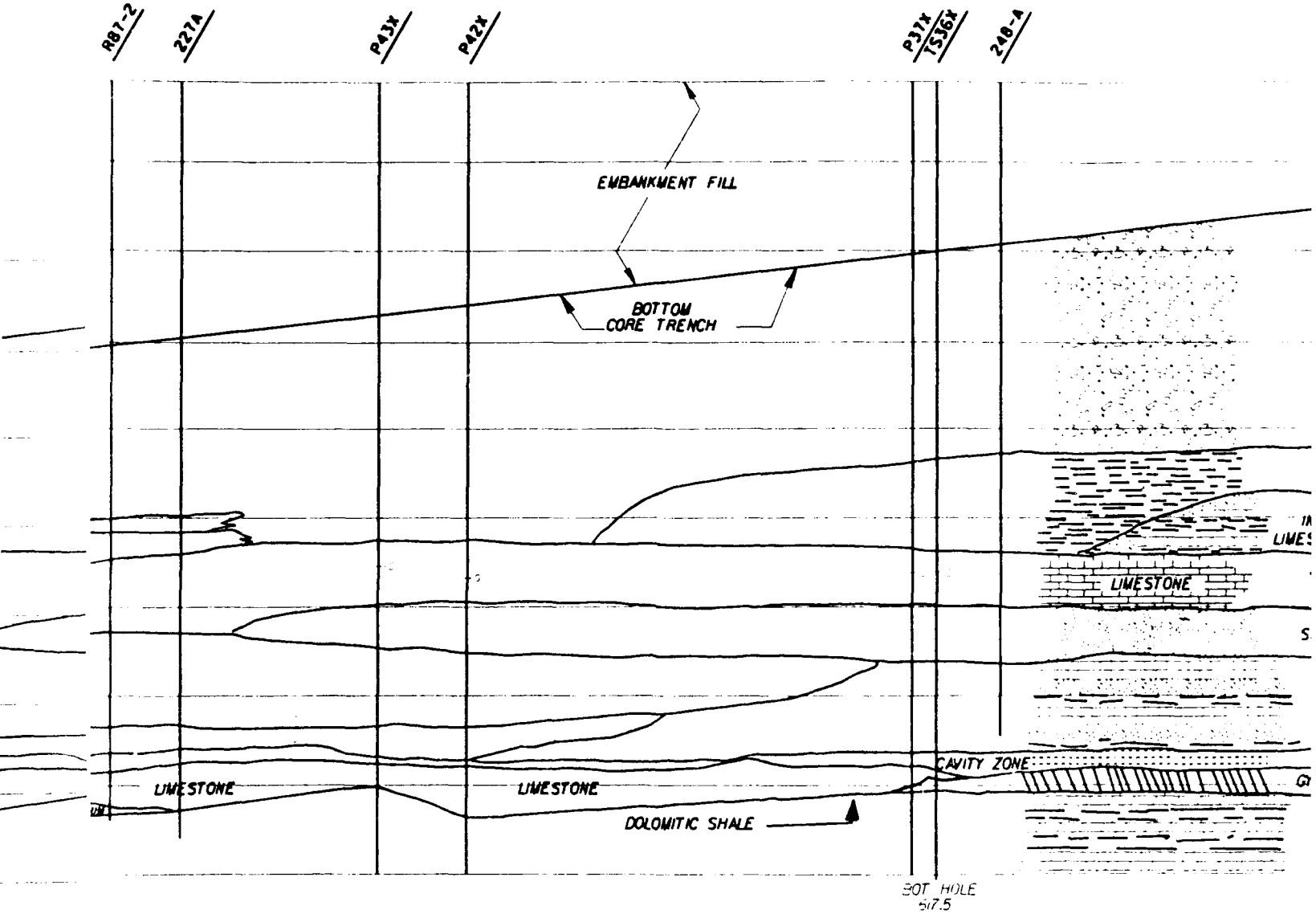
DES MOINES RIVER, IOWA
RED ROCK DAM
REMEDIAL GROUTING
STAGE I
Logs of Exploratory Cores
Sta. 33+40 - 36+05

Scale: 1" = 10'
Date:
Drawing
Sheet reference number:
Solicitation No.
Sheet 4 of

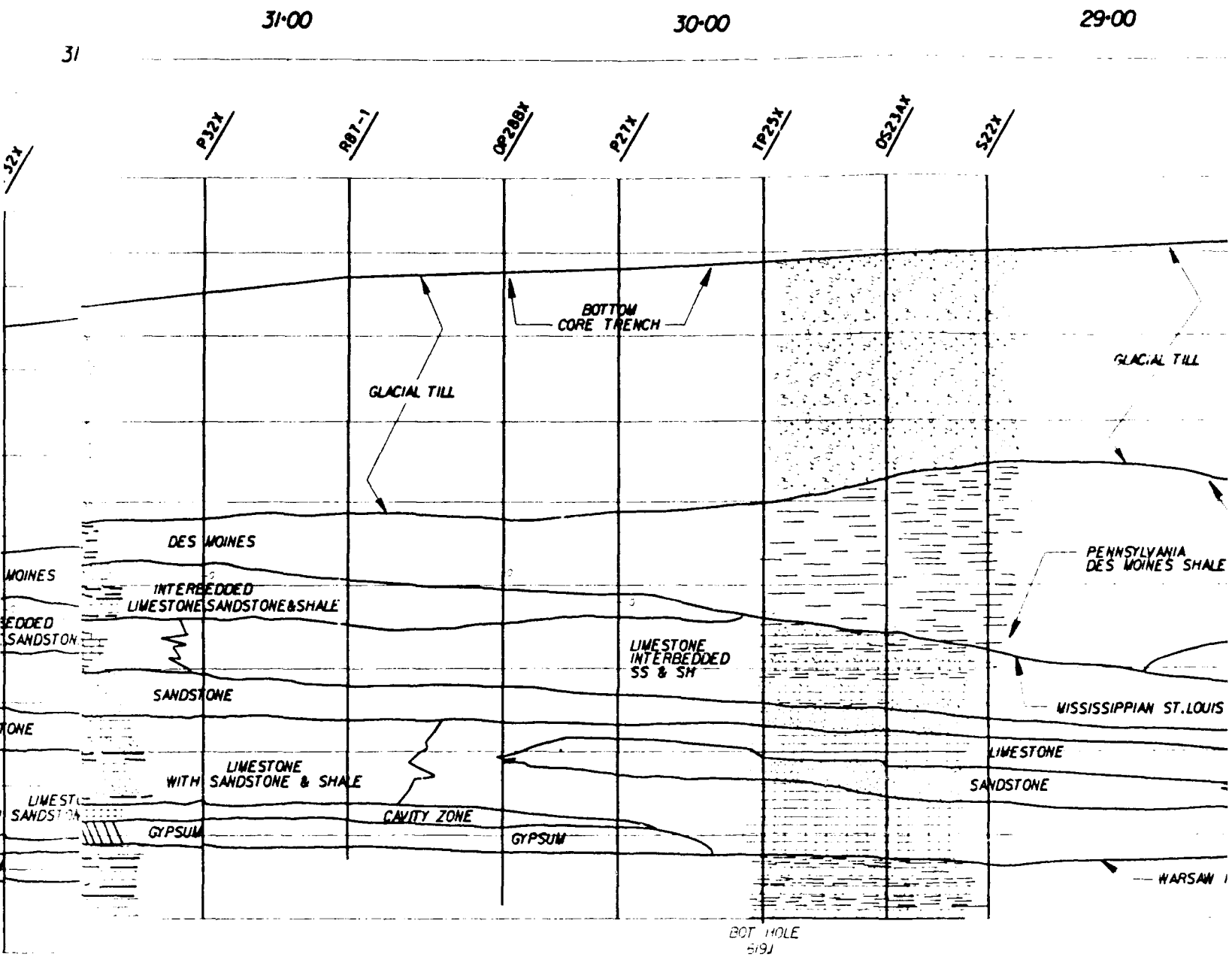
PLA


36·00
35·00
34·00
TP56X
147A
S 53X
P47X
RBT-2
227A
TOP OF DAM 798.0
FLOOD CONTROL 780.0
EMBANKMENT FILL
CONSERVATION POOL 742.0
BOTTOM
CORE TRENCH
GLACIAL TILL
780
760
740
720
700
680
660
640
620
LIMESTONE
SANDSTONE
LIMESTONE
SANDSTONE
INTERBEDDED SANDSTONE LIMESTONE & SHALE
CAVITY ZONE
GYPSUM
LIMESTONE
WARSAW
LIMESTO
36·00
35·00
34·00

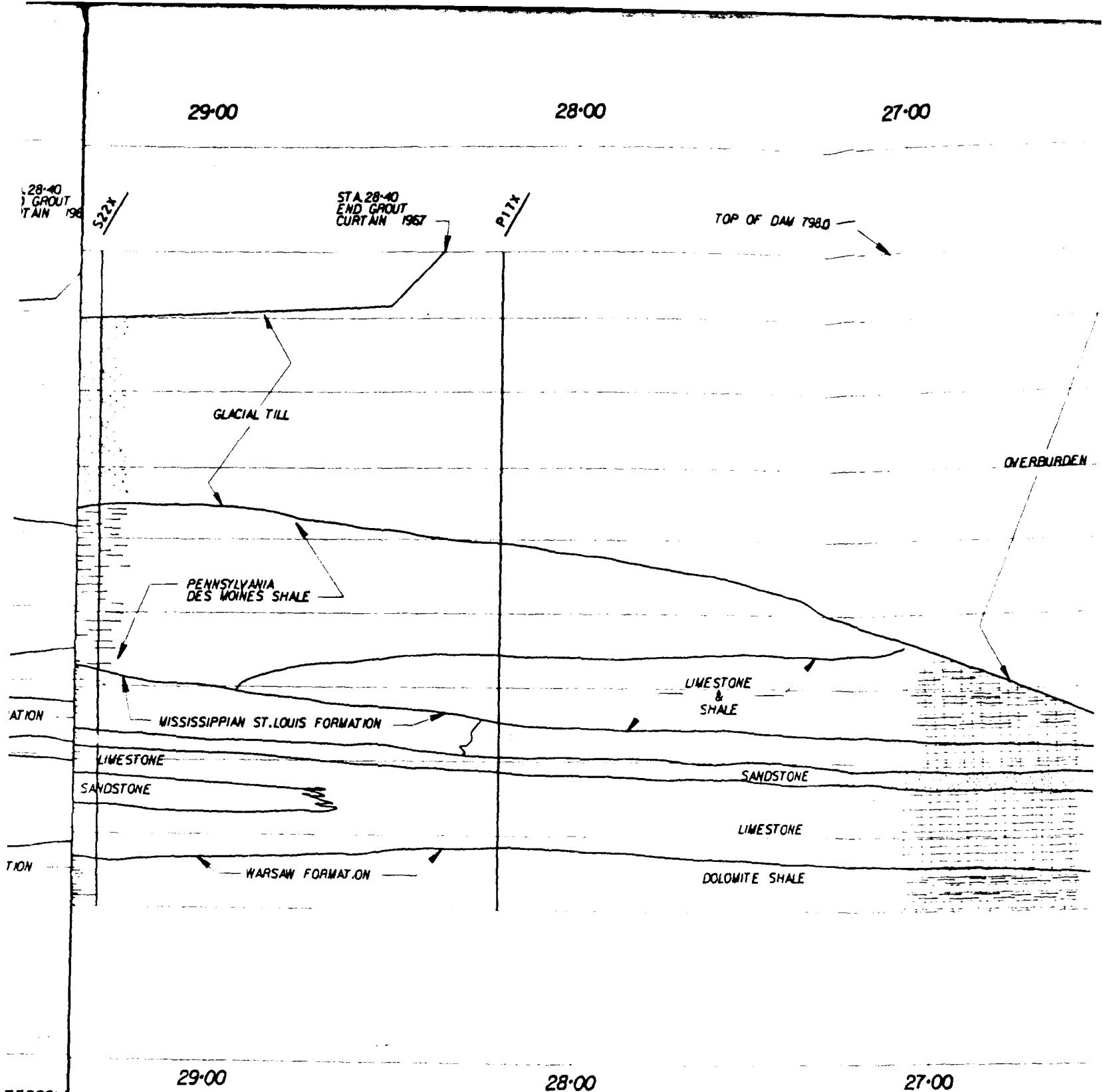
34·00 33·00 32·00



'4·00 33·00 32·00



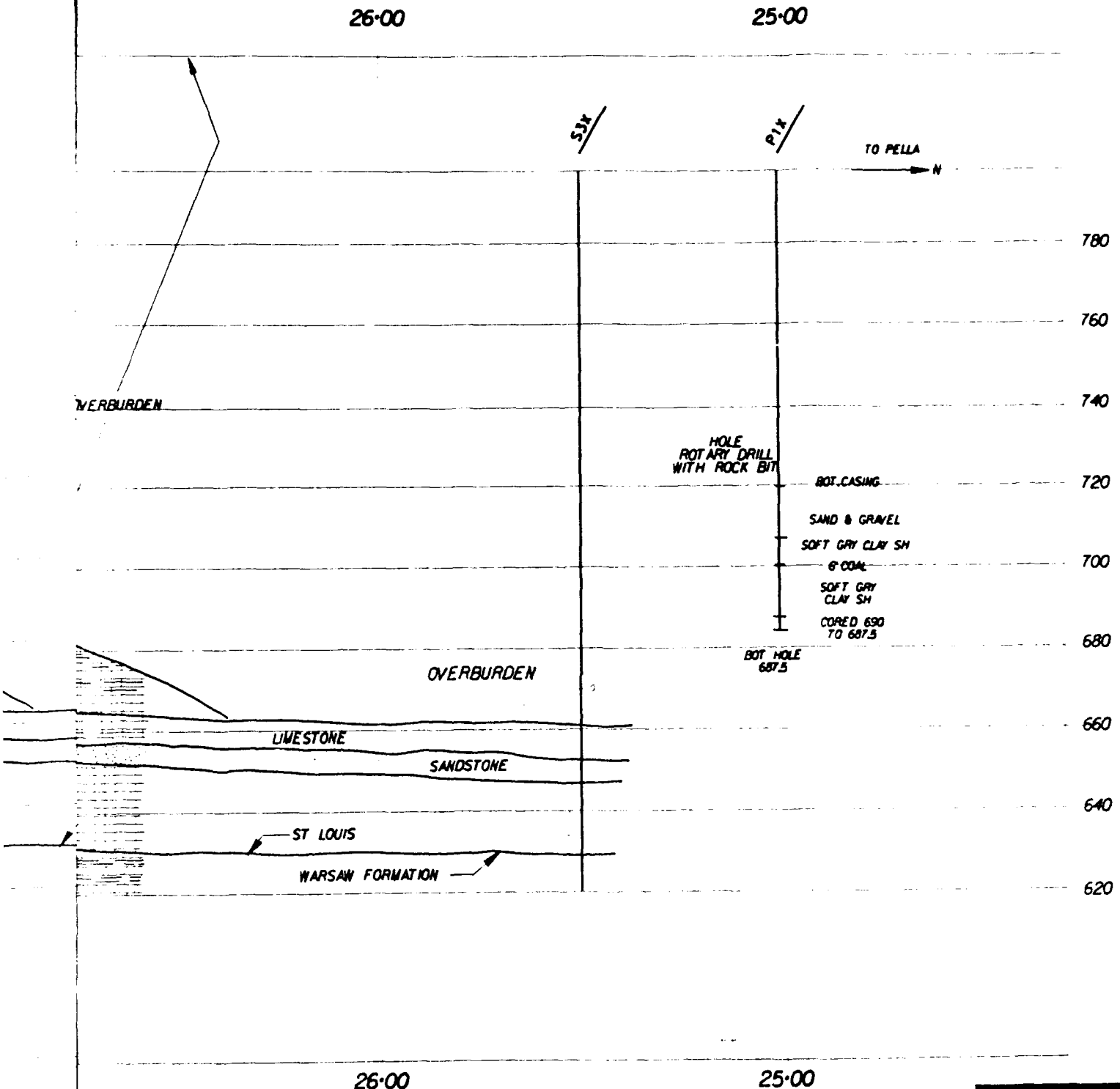
RED ROCK DAM
GEOLOGIC SECTION
STA. 25·00 TO STA. 36·00, 15' U/S
SECTION LOOKING U/S



NOTE: INTERPOLATED ELEVATIONS FROM FOUNDATION REPORT FOR FOLLOWING:

① LIMITS BOTTON CORE TRENCH
② DES MOINES FORMATION
③ GLACIAL TILL LIMITS

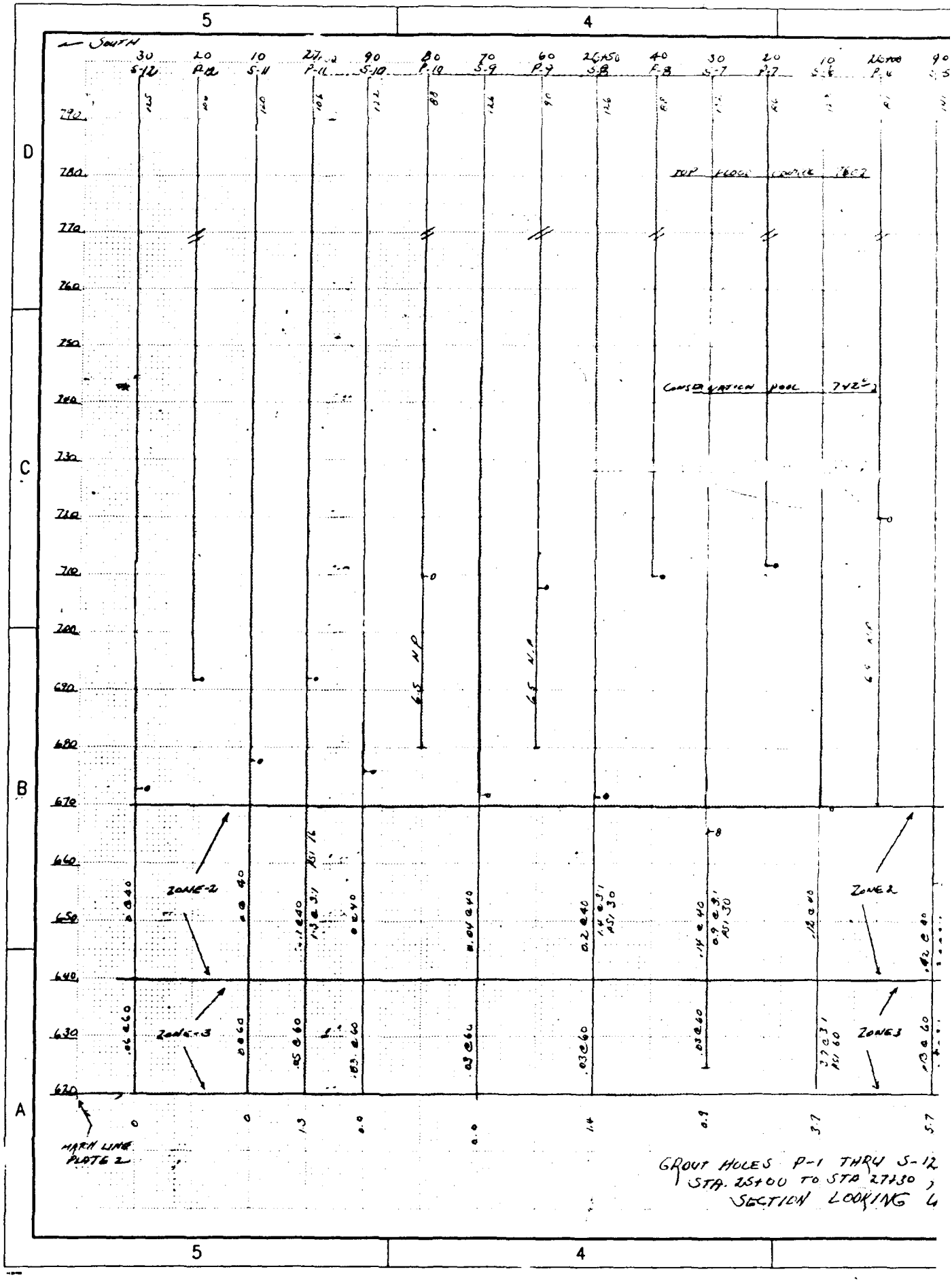
NOTE: BOTTOM CASING SYMBOL - O START CORING THIS CONTRACT



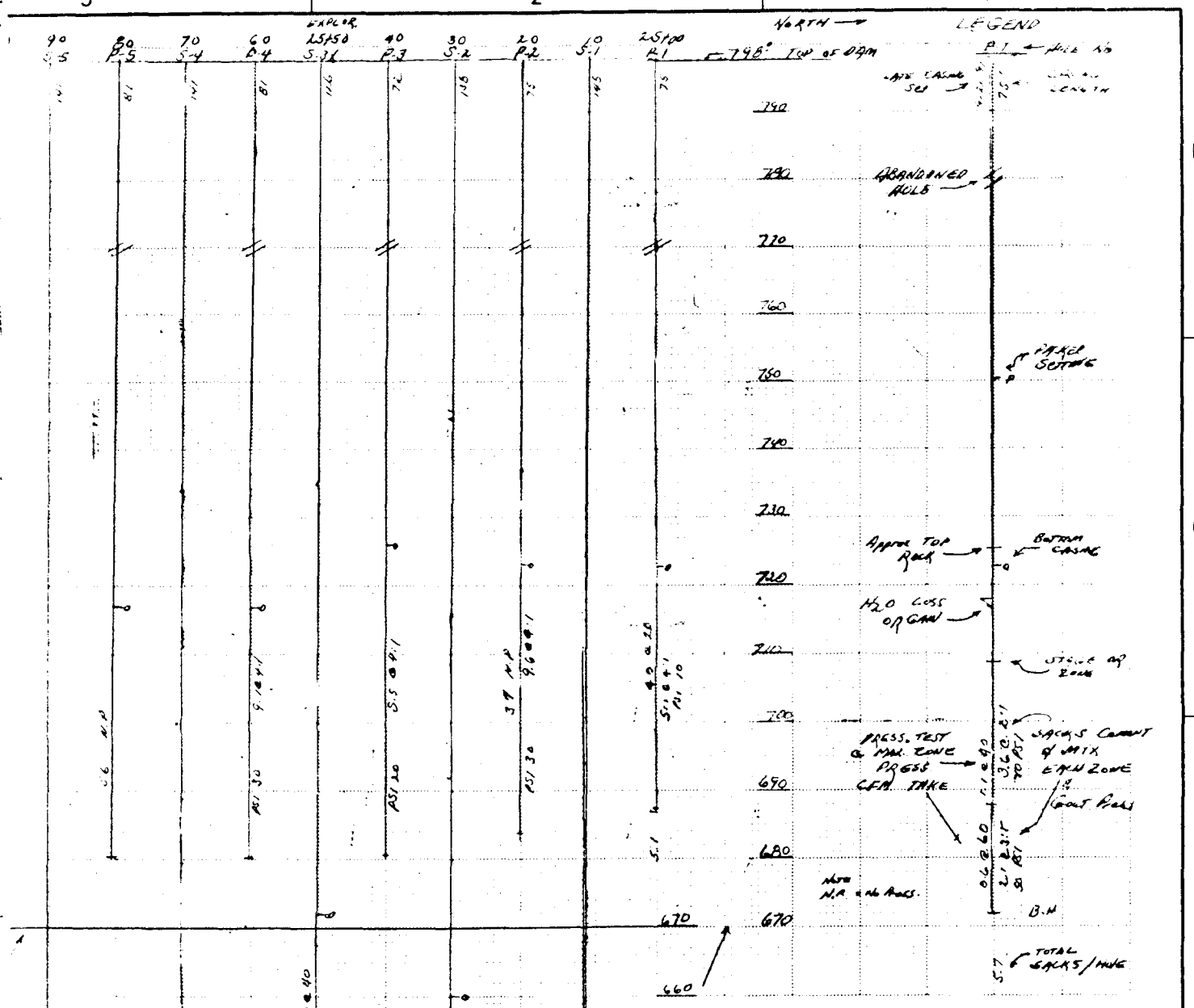
HOLES OW OF CORE HOLES ENDING
TION 620 X IS ELEVATION 620.0
NOTED OTHERWISE NOTED

U. S. ARMY ENGINEER
CORPS OF ENGINEE
ROCK ISLAND, ILL
DES MOINES RIVER,
RAD ROCK DAM
REMEDIAL GROUTIN
STAGE I
GEOLOGIC PROFILE STA. 25+00

PLATE 8



GROUT HOLES P-1 THRU S-12
STA. 25+00 TO STA 27+30
SECTION LOOKING U



Revisions			
Symbol	Description	Date	Approved

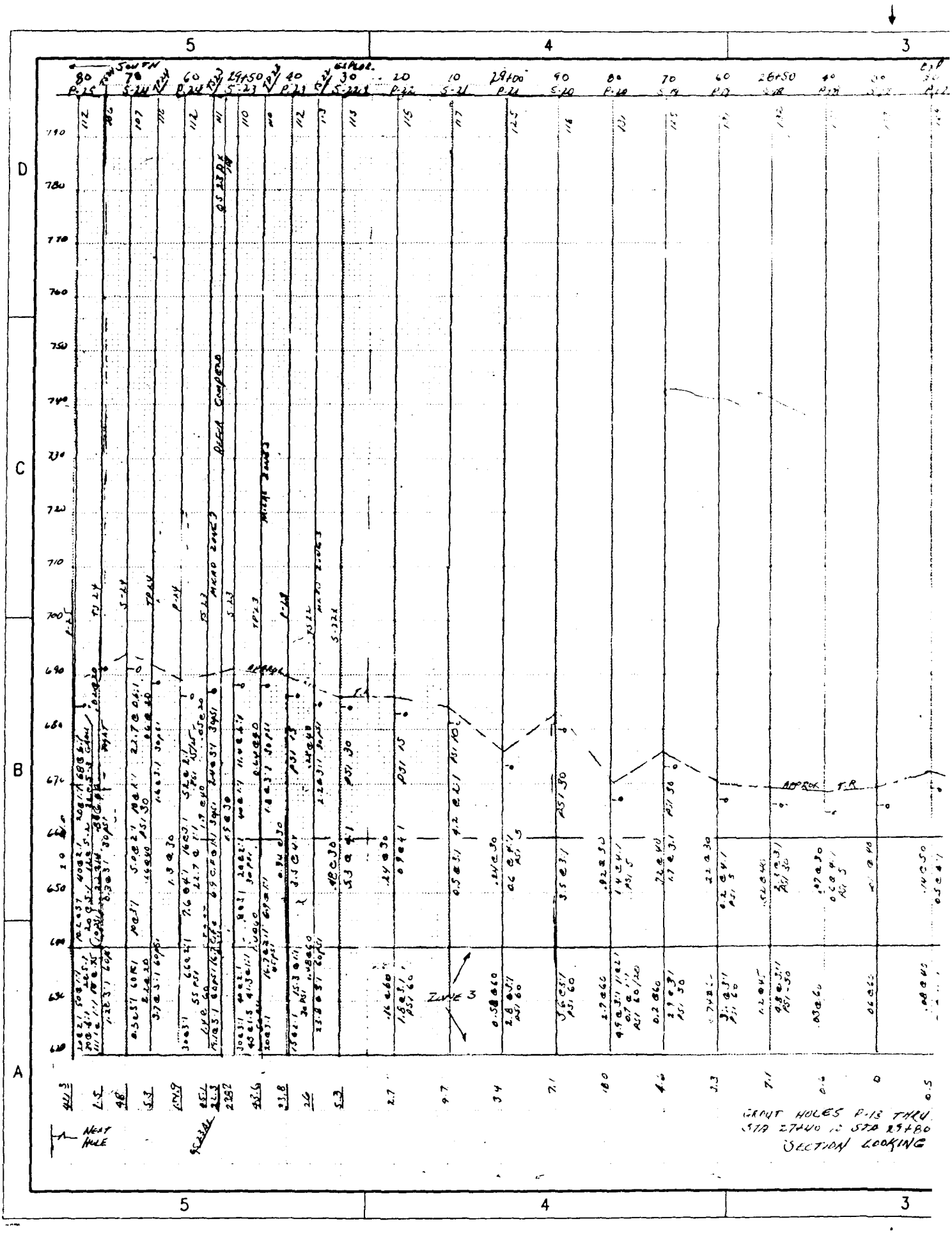
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

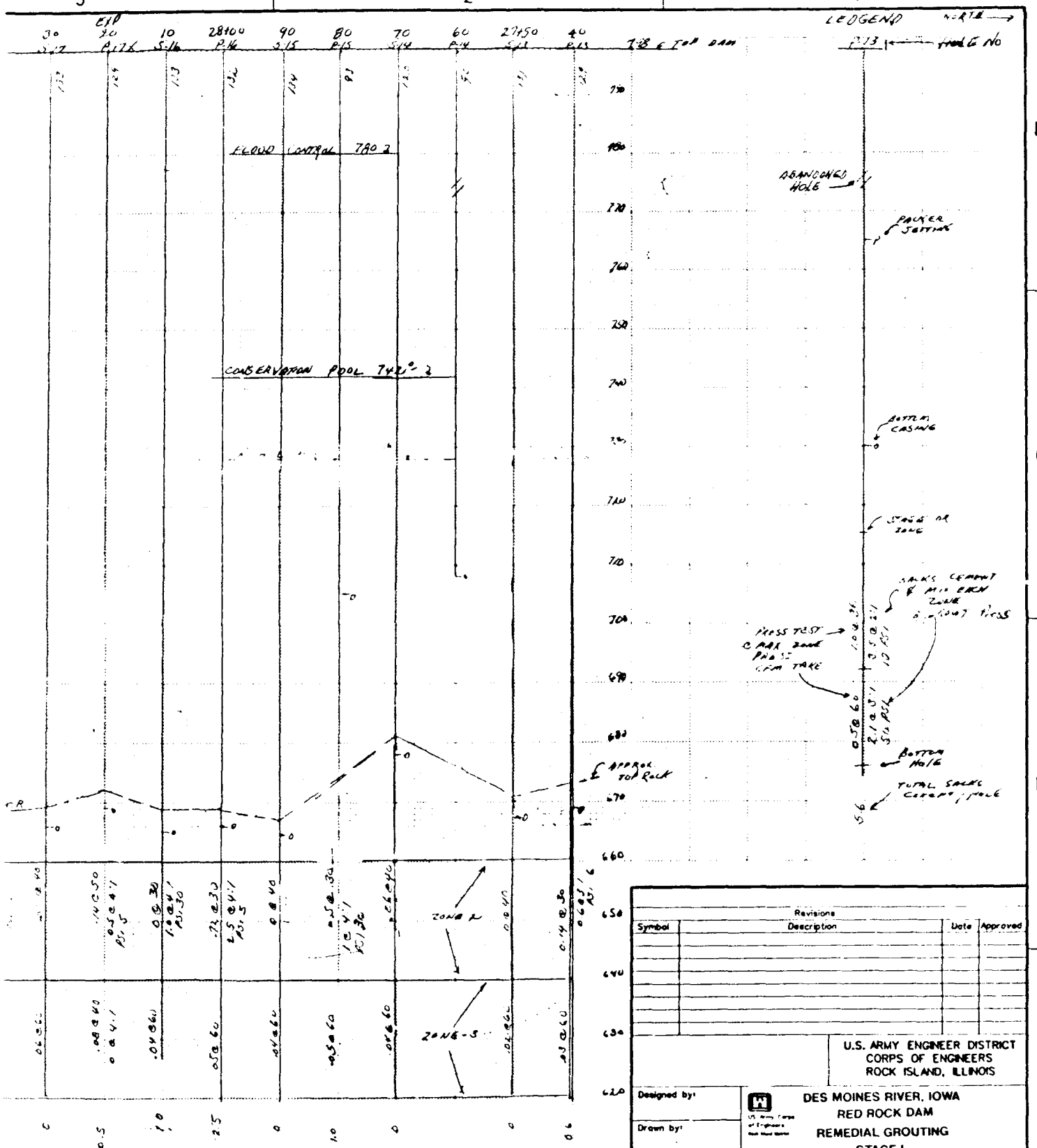
Designed by:
Drawn by:
Checked by:
Reviewed by:
Approved by:

DES MOINES RIVER, IOWA
RED ROCK DAM
REMEDIAL GROUTING
STAGE I
Grouting Profile Sta. 25+00 – 27+30

Scale: 1"=10'
Date:
Drawing Code:
Sheet reference number:
Solicitation Number:
Sheet 1 of 5

PLATE 6a


5
4
3
D
C
B
A
GROUT HOLES P-13 THRU
STA 27+40 TO STA 29+80
LOOKING



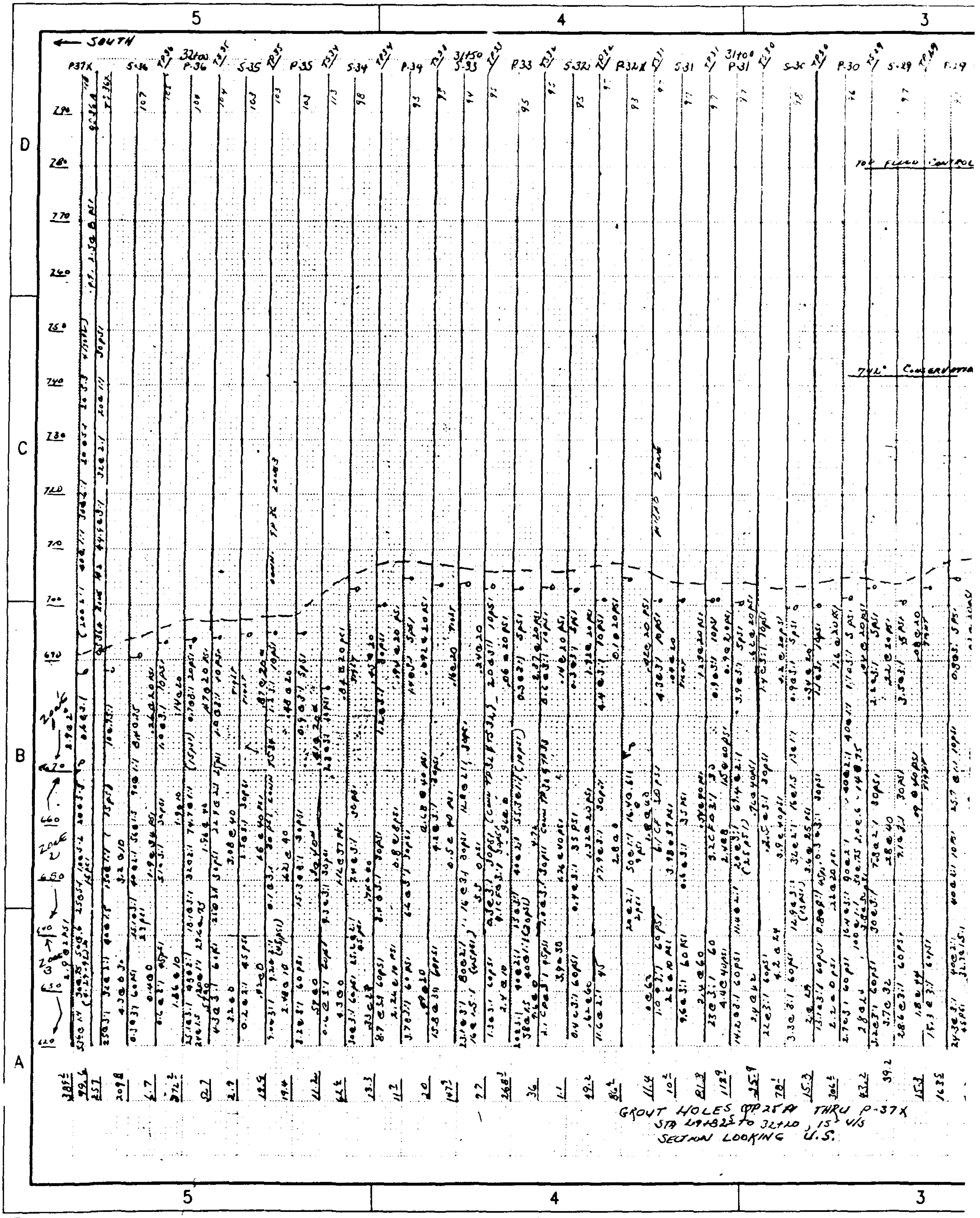
Revisions			
Symbol	Description	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

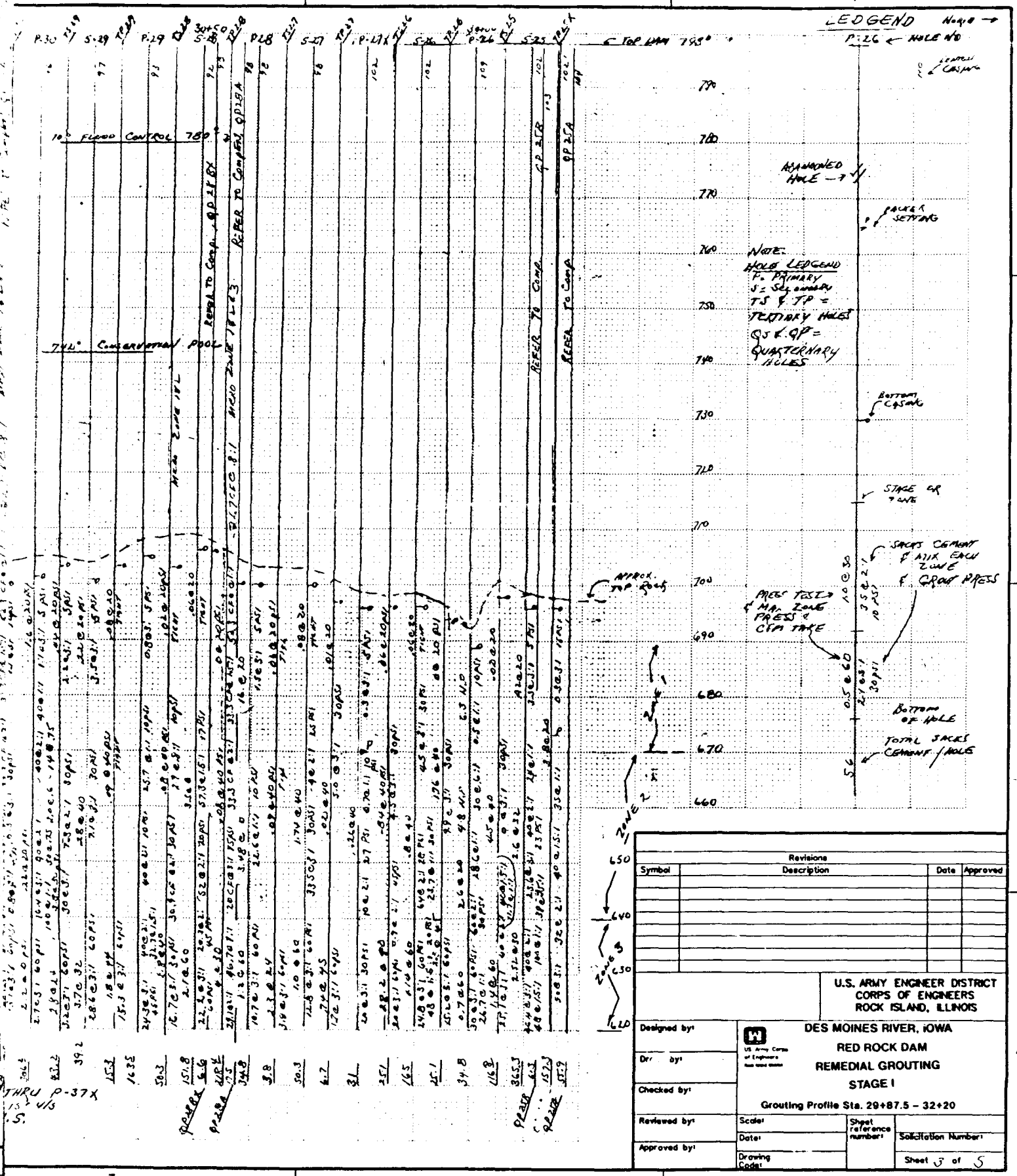
DES MOINES RIVER, IOWA
RED ROCK DAM
REMEDIAL GROUTING
STAGE I
Grouting Profile Sta. 27+40 - 29+00

Designed by:			
Drawn by:			
Checked by:			
Reviewed by:	Scale: 1" = 10'	Sheet reference number:	Solicitation Number:
Approved by:	Date:		
	Drawing Code:		Sheet 2 of 2

PLATE 6b



5
4
3
D
C
B
A
← SOUTH
P37X
S-36
32+00 P-36
S-35
P35
S-34
P-34
31+50 S-33
P33
S-32
P32X
S-31
31+00 P-31
S-30
P-30
S-29
290
280
270
260
250
240
230
220
210
700
690
670
660
650
630
620
ZONE 1
ZONE 2
ZONE 3
TOP FLOOD CONTROL
742' CONSERVATION
GROUT HOLES P25A THRU P-37X
STA 29+82.5 TO 32+20, 15' U/S
SECTION LOOKING U.S.



Revisions			
Symbol	Description	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

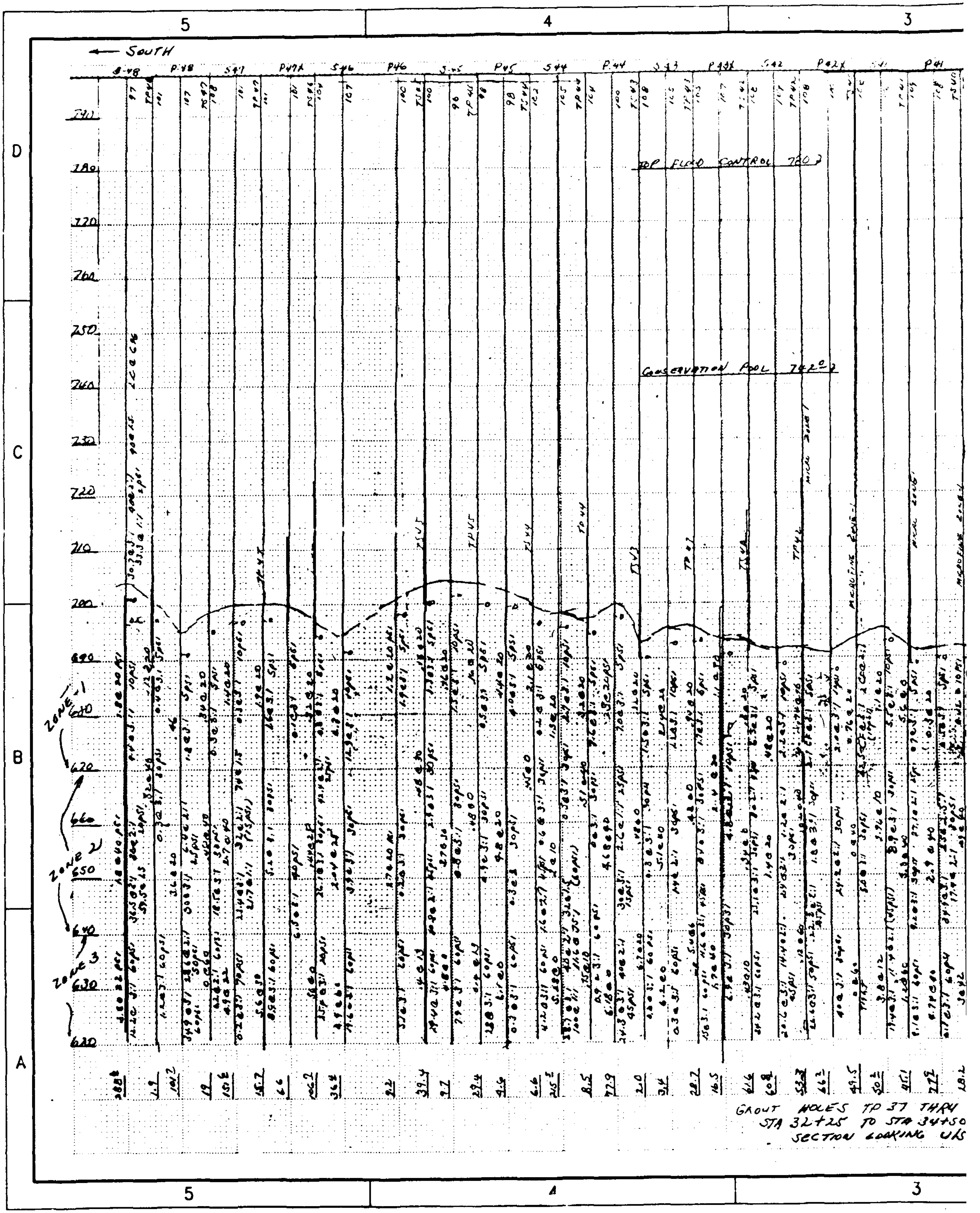
Designed by:
Drn by:
Checked by:
Reviewed by:
Approved by:

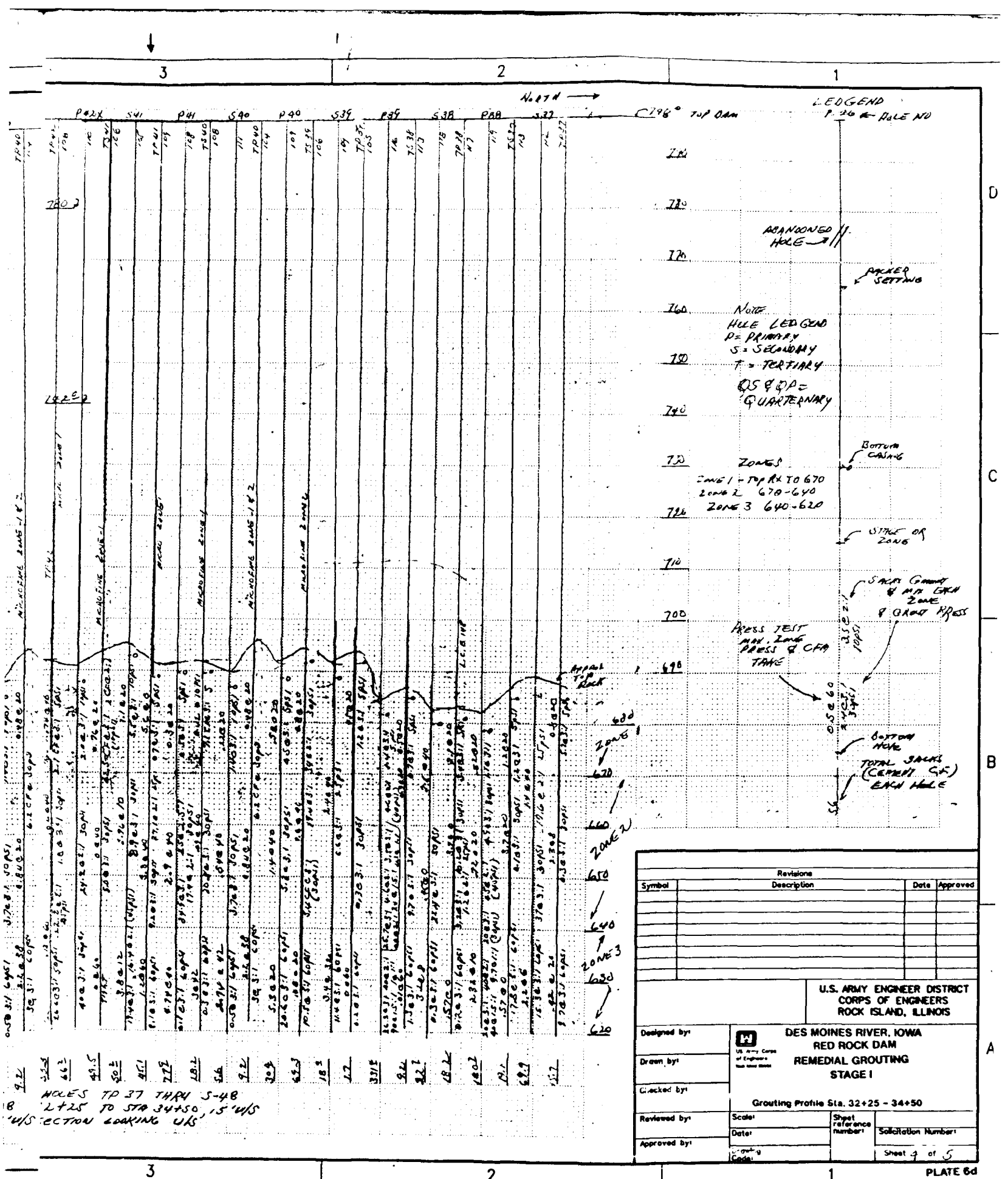
US Army Corps of Engineers

DES MOINES RIVER, IOWA
RED ROCK DAM
REMEDIAL GROUTING
STAGE I
Grouting Profile Sta. 29+87.5 – 32+20

Scale:
Date:
Drawing Code:
Sheet reference number:
Solicitation Number:
Sheet 3 of 5

PLATE 6c


← SOUTH
TOP FLOOD CONTROL
CONSERVATION POOL
ZONE 1
ZONE 2
ZONE 3
GROUT HOLES TP 37 THRU
STA 32+25 TO STA 34+50
SECTION LOOKING U/S



Revisions			
Symbol	Description	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

Designed by:
Drawn by:
Checked by:
Reviewed by:
Approved by:

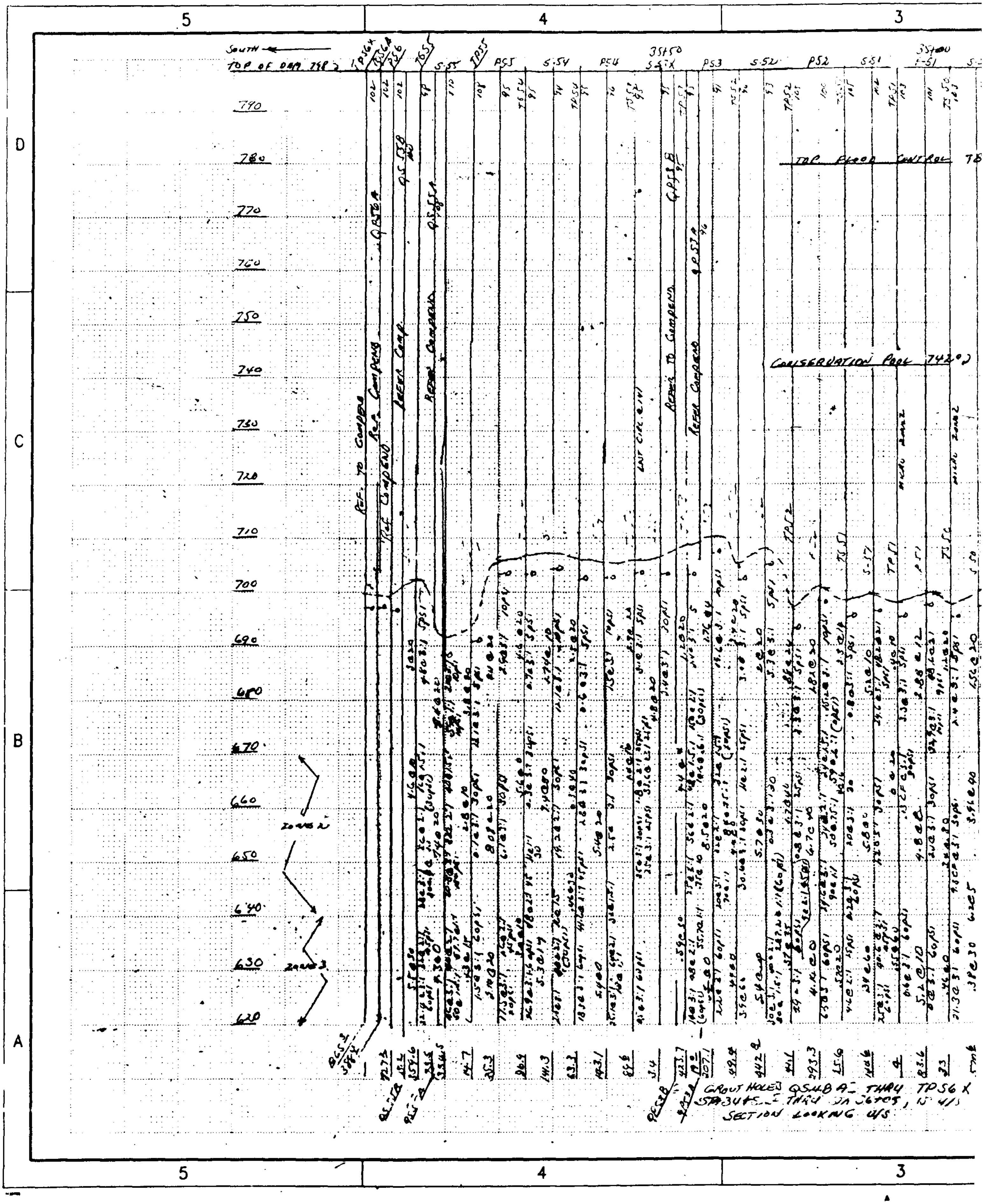
US Army Corps of Engineers

DES MOINES RIVER, IOWA
RED ROCK DAM
REMEDIAL GROUTING
STAGE I

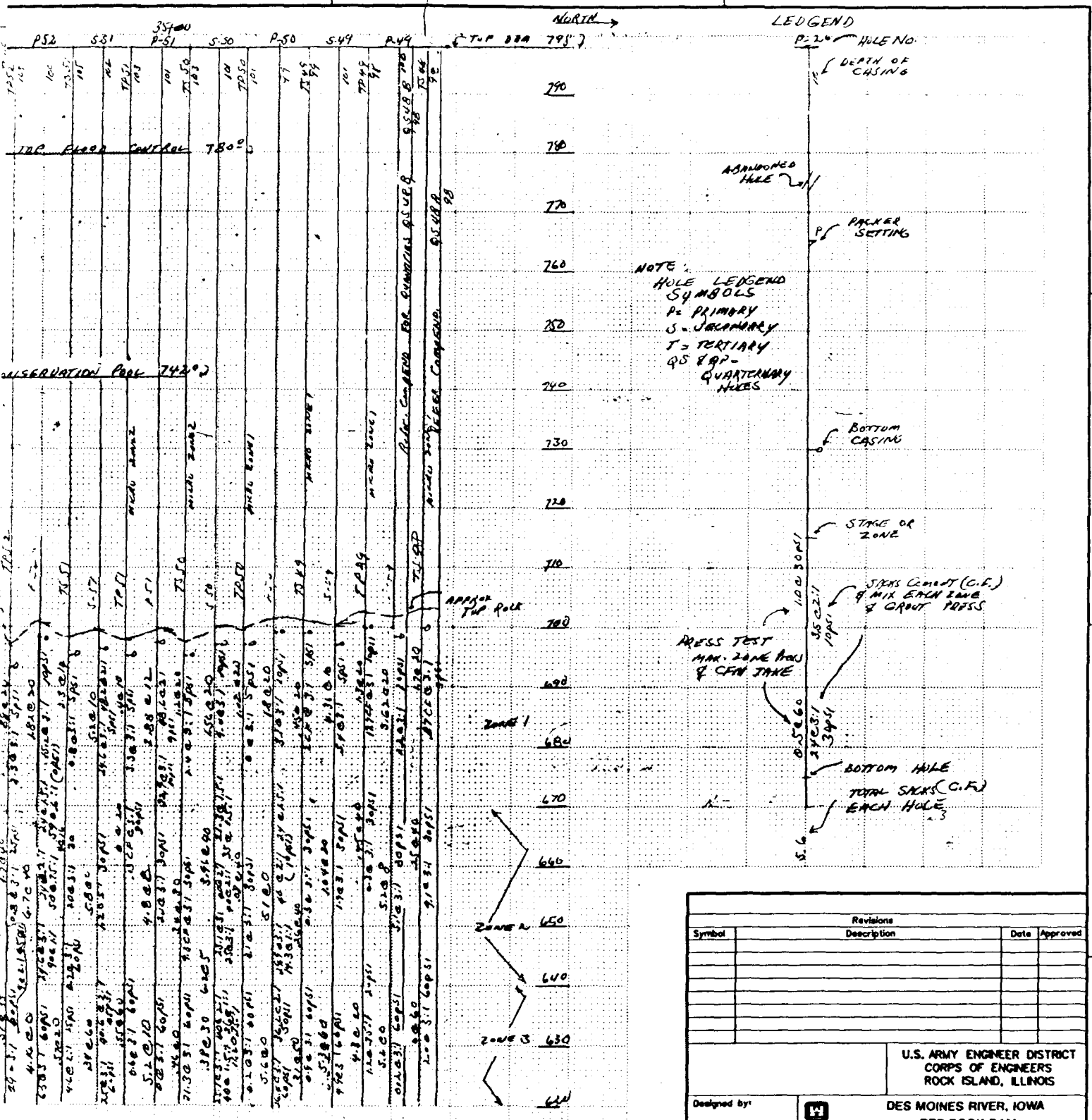
Grouting Profile Sta. 32+25 - 34+50

Scale:
Date:
Sheet reference number:
Solicitation Number:
Grouting Code:
Sheet 9 of 5

PLATE 6d



5
4
3
D
C
B
A
SOUTH
TOP OF DAM
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
TOP FLOOD CONTROL
CONSERVATION POOL
ZONE 2
ZONE 3
REF. TO COMPEND
SECTION LOOKING U/S



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DES MOINES RIVER, IOWA
RED ROCK DAM
REMEDIAL GROUTING
STAGE I

Grouting Profile Sta. 34+52.5 – 36+05

Scale:
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Drawing Code:
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Sheet 5 of 5

PLATE 6e